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PROCEEDINGS OF THE WORLD SCIENTIFIC CONFERENCE ON THE BIOLOGY AND CULTURE OF SHRIMPS AND PRAWNS

ACTES DE LA CONFÉRENCE SCIENTIFIQUE MONDIALE SUR LA BIOLOGIE ET L'ÉLEVAGE DES CREVETTES

ACTAS DE LA CONFERENCIA CIENTIFICA MUNDIAL SOBRE BIOLOGIA Y CULTIVO DE CAMARONES Y GAMBAS

Mexico City, Mexico, 12-21 June 1967
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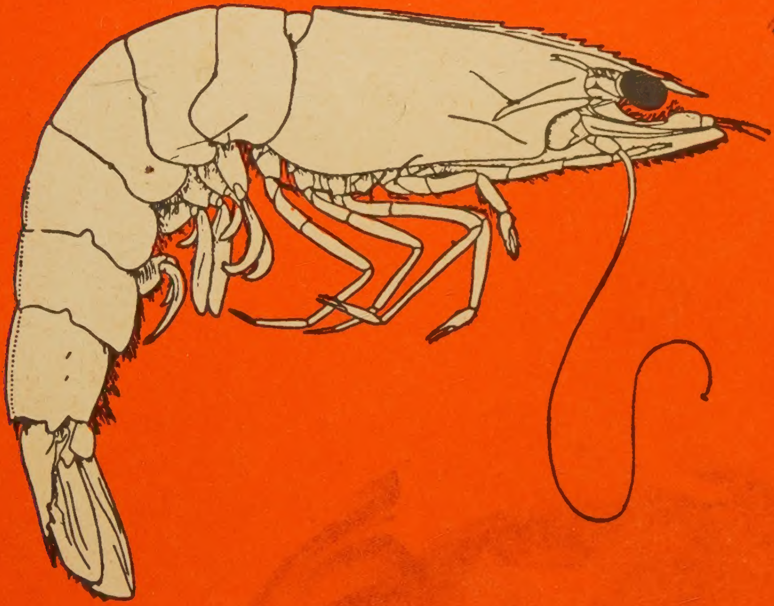

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ORGANISATION DES NATIONS UNIES POUR L'ALIMENTATION ET L'AGRICULTURE
ORGANIZACION DE LAS NACIONES UNIDAS PARA LA AGRICULTURA Y LA ALIMENTACION

ROME, 1969

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VOLUME III - EXPERIENCE PAPERS

VOLUME III - COMPTES RENDUS D'EXPERIENCES

VOLUMEN III - DOCUMENTOS DE INVESTIGACION

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ORGANISATION DES NATIONS UNIES POUR L'ALIMENTATION ET L'AGRICULTURE
ORGANIZACION DE LAS NACIONES UNIDAS PARA LA AGRICULTURA Y LA ALIMENTACION
Rome, October 1969 Rome, octobre 1969 Roma, octubre 1969

PREPARATION OF THIS VOLUME

This edition (Volume III) consists of the remainder of the corrected experience papers contributed to the World Scientific Conference on the Biology and Culture of Shrimps and Prawns, held in Mexico City, Mexico, from 12 to 21 June, 1967. The papers were distributed at that time to the participants and authors.

The first volume contained the Report of the Conference, and the review, regional summary and some experience papers were included in the second volume. The subsequent and ultimate issue (Volume IV) will contain the species synopses papers.

The views expressed in the contributions are those of the authors and not necessarily of the Food and Agriculture Organization of the United Nations.

Dr. D.I. Williamson and Mr. R.F. Temple assisted in the editing of some of the contributions and Dr. L.B. Holthuis assisted in the nomenclature.

PREPARATION DU PRESENT VOLUME

La présente édition (Volume III) contient le reste des comptes rendus d'éxperiences présentés à la Conférence scientifique mondiale sur la biologie et l'élevage des crevettes, tenue à Mexico (Mexique) du 12 au 21 juin, 1967. Ces comptes rendus furent alors distribués aux participants et aux auteurs.

Le premier volume contenait le rapport de la Conférence; les exposés généraux, le résumé régional et quelques comptes rendus d'éxpériences furent inclus dans le second volume. Le volume suivant (Volume IV) contiendra les synopsis d'espèces.

Les opinions exprimées dans les communications sont celles des auteurs et ne représentent pas nécessairement celles de l'organisation des Nations Unies pour l'alimentation et l'agriculture.

M. D.I. Williamson et M. R.F. Temple ont collaboré à la mise au point de certaines des communications et M. L.B. Holthuis a collaboré à la nomenclature.

PREPARACION DE ESTE VOLUMEN

Esta edición (Volumen III) contiene la revisión del resto de los documentos de investigación presentados a la Conferencia Cientifica Mundial sobre Biología y Cultivo de Camarones y Gambas, celebrada en Ciudad de México, México, del 12 al 21 junio de 1967. Estos documentos fueron distribuidos au la fecha mencionada entre los participantes y autores.

El primer volumen contiene el Informe de la Conferencia y el segundo volumen los documentos de reseña, resúmenes regionales y documentos de investigación. El ultimo por salir (Volumen IV) contendrá las sinopsis de especies.

Las opiniones expresadas en los documentos son las de los autores y no reflejan necesariamente las de la Organización de las Naciones Unidas para la Agricultura y la Alimentación.

El Dr. D.I. Williamson y el Sr. R.F. Temple prestaron su colaboración para la redacción de algunos de los documentos y el Dr. L.B. Holthuis colaboró en la nomenclatura.

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THE GENERAL BIOLOGY AND DEVELOPMENT OF Macrobrachium rosenbergii (DE MAN)[1]

by

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Abstract

The paper is based on experiments and observations made at Penang, Malaysia. *Macrobrachium rosenbergii* is widely distributed in fresh and brackish waters in southeast Asia. It is omnivorous and its feeding behaviour is described. An account is given of moulting, mating and egg-laying and of embryonic, larval and postlarval development. The larva undergoes 11 moults before reaching the juvenile stage, but only 8 larval stages are morphologically distinct. At 26 to 28°C, embryonic development takes 19 to 20 days and larval development takes 30 to 45 days; when cultured in ponds, the prawns become fully grown 7 to 8 months after metamorphosis.

The larval stages require brackish water for survival. Under natural conditions, the juveniles migrate to fresh water and adult females release their larvae in the upper parts of estuaries.

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[1] An FAO/Malaysian Research Project, conducted at the Fisheries Research Institute, Glugor, Penang, Malaysia

E/30

BIOLOGIE GENERALE ET DEVELOPPEMENT DE Macrobrachium rosenbergii (DE MAN)

Résumé

La communication est fondée sur des expériences et observations faites à Penang (Malaisie). Macrobrachium rosenbergii, largement réparti dans les eaux douces et saumâtres de l'Asie du Sud-Est, est une crevette omnivore dont on décrit les habitudes alimentaires. Le document traite également de la mue, de l'accouplement et de la ponte, ainsi que du développement embryonnaire, larvaire et postlarvaire. La larve mue onze fois avant de parvenir au stade juvénile, mais du point de vue morphologique on ne distingue que huit stades larvaires. A 26-28°C, le développement embryonnaire prend de 19 à 20 jours et le développement larvaire de 30 à 45. Elevées en étang, les crevettes atteignent leur taille adulte de 7 à 8 mois après la métamorphose.

La survie des stades larvaires exige une eau saumâtre. Dans les conditions naturelles, les jeunes émigrent en eau douce et les femelles adultes déposent leurs larves dans la partie amont des estuaires.

BIOLOGIA Y DESARROLLO GENERAL DE Macrobrachium rosenbergii (DE MAN)

Extracto

Informa el autor sobre los experimentos y observaciones realizados en Penang, Malasia. Macrobrachium rosenbergii está ampliamente distribuido en las aguas dulces y salobres del Asia sudoriental; es omnívoro y se describen sus hábitos alimentarios. Explica su autor la muda, apareamiento, desove y desarrollo embriónico, larval y postlarvar. La larva experimenta 11 mudas antes de alcanzar la fase juvenil, pero solamente ocho fases larvales son morfológicamente diferentes. Entre 26 y 28°C el desarrollo embrional tarda de 19 a 20 días y el larval de 30 a 45 días; cuando se crían en estanques, los camarones adquieren el pleno desarrollo de 7 a 8 meses después de la metamorfosis.

Las larvas necesitan agua salobre para sobrevivir. En condiciones naturales, los ejemplares juveniles emigran al agua dulce y las hembras adultas desprenden sus larvas en las partes altes de los estuarios.

1 INTRODUCTION

Macrobrachium rosenbergii, the long-legged giant prawn of fresh and brackish waters, has since time immemorial been highly esteemed as food by people of the tropical countries of Asia and the Far East. The popularity of this prawn has grown rapidly and the demand for it is getting progressively greater. Methods for increasing its production are therefore necessary.

Prawn culture in its true sense is only at its initial stage of development, although various traditional methods of inducing young prawns to enter ponds, "bheris", tanks, rice fields, etc, are being popularly practised in several countries, especially India and Pakistan. The prawns grow to edible size in these enclosures. Difficulties in getting sufficient supply of young prawns has been a major factor limiting the development and expansion of prawn culture.

The production of young prawns of this species under controlled conditions has been attempted by fisheries' workers in several countries, but without success.

Since the summer of 1959, series of experiments on the breeding, rearing and culturing of this prawn under controlled conditions have been conducted at the Malaysian Fisheries Research Institute, Glugor, Penang, Malaysia, under the FAO/Malaysian Inland Fisheries Development Project. After several years of work and many failures, techniques for rearing the various larval stages and methods for culturing young stages to adults have been developed, and at the same time a considerable number of interesting facts about the biology and habits of this prawn have been observed. The results and observations obtained from these experiments and field work are summarized in this paper.

In view of the great interest of the various nations in this young but highly promising field of aquiculture, it is the hope of the writer that this paper may serve to stimulate greater enthusiasm and to promote further studies leading to a rapid development of large scale prawn culture for food and profit.

2 GENERAL BIOLOGY

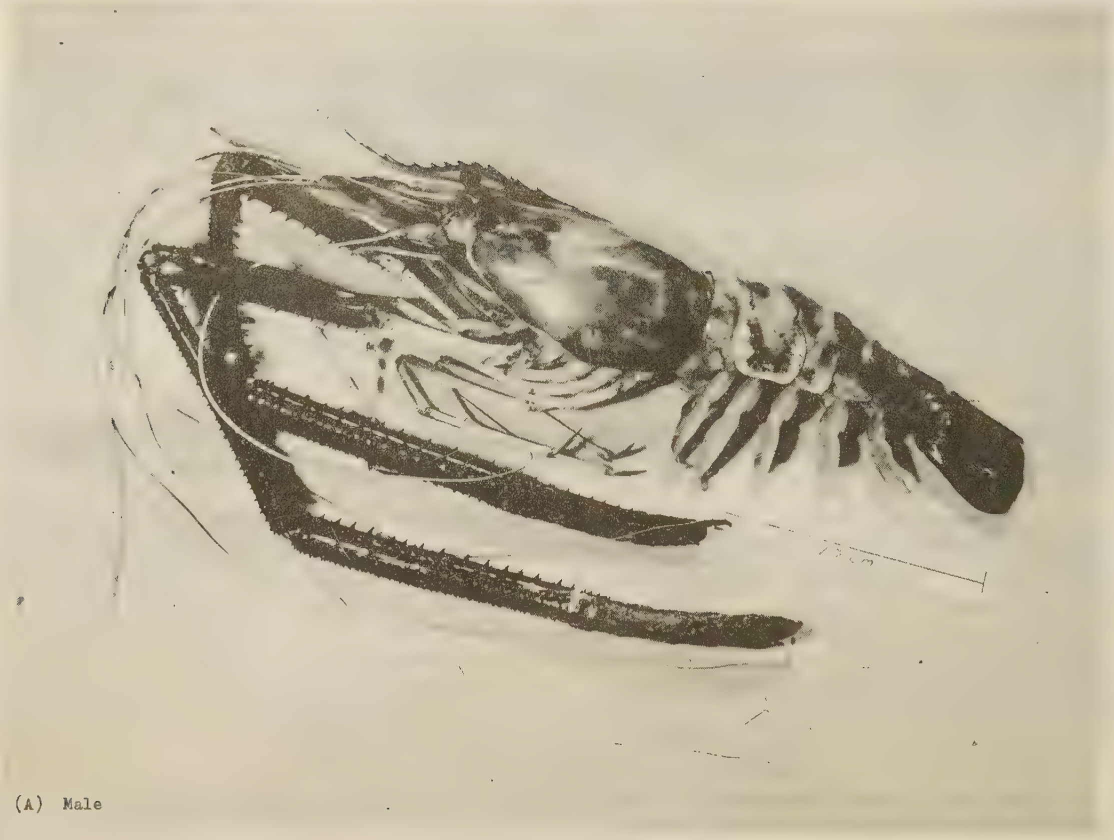
2.1 General distribution

The giant prawn, Macrobrachium rosenbergii, locally known in Malaya as "Udang Galah" (Fig. 1), is widely distributed in most of the tropical and subtropical areas of the Indo-Pacific Region, including East Pakistan, India, Ceylon, Burma, Thailand, Malaysia, Indonesia, Philippines, Cambodia and Vietnam. It occurs the whole year round and is present in both fresh and brackish waters. It inhabits most of the rivers, especially the lower reaches which are influenced by tides, but also occurs up to at least 200 km from the coast, and is present in lakes, water reservoirs, mining pools, irrigation canals and even some padi-fields which have direct or indirect access to the rivers.

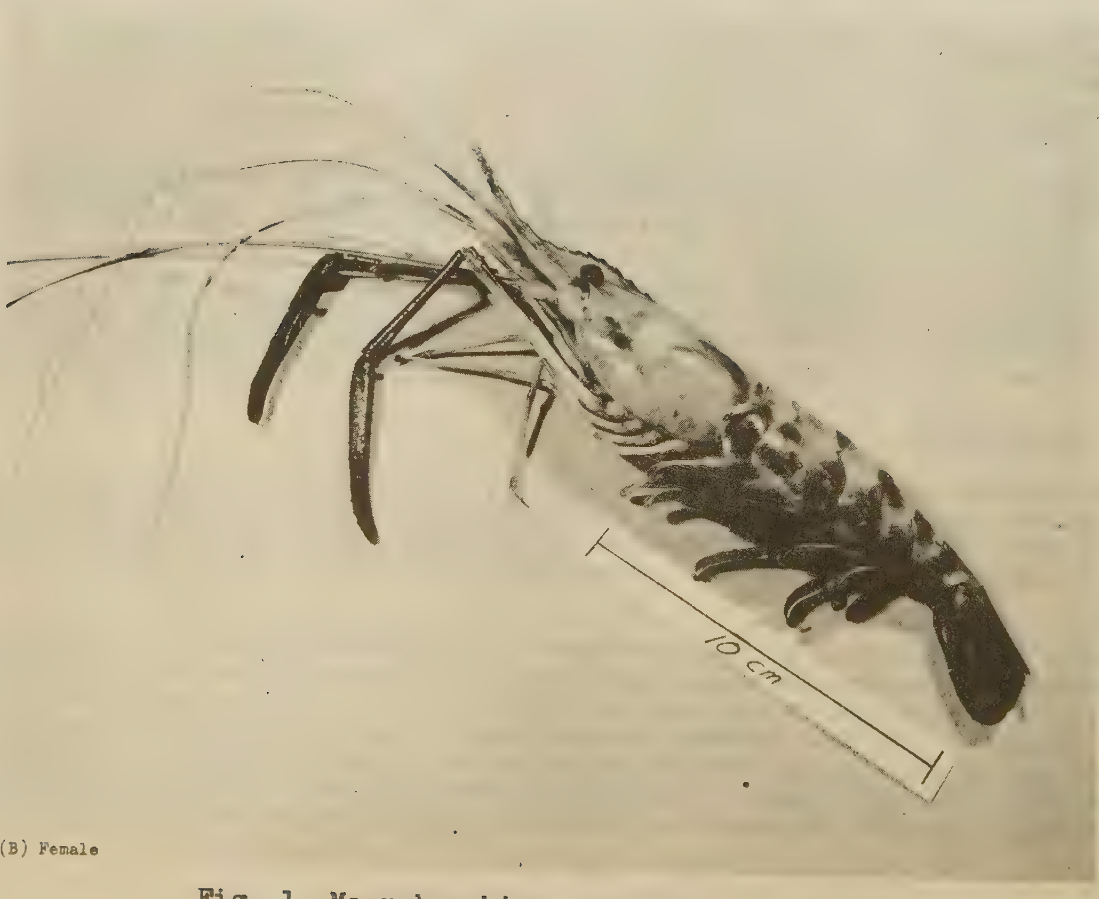
2.2 Food habits

This prawn is omnivorous and eats frequently and greedily. Common items of food include aquatic worms, aquatic insects and insect larvae, small molluscs and crustaceans, flesh and offal of fish and other animals, grain, seeds, nuts, fruits, algae and tender leaves and stems of aquatic plants. When sufficiently hungry it may even become cannibalistic.

Food is located mainly by smell and touch. When searching for food the filaments of the antennae and antennules sweep about actively. When a large piece of food is found, it is picked up and brought to its mouth by its first and second pairs of thoracic legs together. If small pieces of food, such as grains of rice, are found, they are picked up individually and are brought to the mouth one by one by the pincers of the first pair of thoracic legs. Immediately after the grain is taken by the mouth the empty pincer is again employed for picking up another piece, and an actively feeding



(A) Male



(B) Female

Fig. 1 Macrobrachium rosenbergii, adult.
(A) Male. (B) Female

specimen may frequently be seen holding two pieces of food, one in each chela, while at the same time there is already one piece in its mouth.

2.3 Moulting and growth

At moulting, the old cuticle is usually cast in less than ten minutes. The prawn stops other activities, bends its body and exerts strong internal pressure. The internal pressure increases, causing a dorsal transverse split in the membranous part between the carapace and the abdomen. The prawn then bends itself almost in the form of an inverted U, and further internal pressure and repeated flexing of the body soon push part of the body smoothly out through the dorsal split. When much of the body has emerged a sudden jerk frees the entire animal, including all its appendages, from its old shell. Longitudinal splits may also occur along the sides of some segments of some of the larger thoracic appendages. Regenerated missing appendages, which are formed under the old shell, are all set free after moulting.

The frequency of moulting depends on the age of the individual and the amount and quality of food taken. Young specimens moult more frequently than old ones: individuals taking ample amounts of good quality food moult sooner than those taking less or poorer food. Every sexually mature female moults shortly before mating (the pre-mating moult).

Growth rate is rather rapid. Cultured in ponds with good water conditions and ample food, the average growth rate, from young prawns (60 days old, counting from time of metamorphosis) to adults, has been found to be as follows:

Time in pond	Average length (cm)		Average Weight (g)
	Tip of rostrum to tip of telson	Tip of antennal scale to tip of telson	
1st day	5.5	5.0	2.0
1 month	7.6	6.5	4.5
2 months	11.0	9.5	10
3 "	14.0	12.5	25
4 "	18.0	16.5	60
5 "	21.0	19.5	100
6 "	22.5	20.5	125

The growth rate of young males and females is about the same. After reaching a length of about 18 cm and a weight of 60 g, the growth rate of females decreases, and there is little growth beyond about 22 cm in length and 120 g in weight. The males keep on growing to about 200 g each.

2.4 Mating and egg-laying

2.4.1 Characteristics of mature male and female When mature, male prawns are considerably larger than females. The second thoracic legs are extremely long and rather thick, the head is big, the abdomen compact with very little space between the pleura, and the genital pores are at the bases of the 5th thoracic legs.

Females are in general smaller than the males, the second thoracic legs are shorter and more slender and the head is smaller. There is a spacious brood chamber below the abdomen, formed by the downward prolongation of the abdominal pleura, and the genital pores are at the bases of the third thoracic legs.

2.4.2 Characteristics of sexually ripe female The ripe ovaries can be seen through the carapace as large orange coloured masses occupying a large portion of the dorsal and lateral parts of the cephalothorax. The abdominal pleura, which are ordinarily bent slightly inwards towards the pleopods, become slightly distended and arched outward, so that the brood chamber is enlarged. The basal segments of the first four pairs of pleopods are elongated and are provided with tufts of long ovigerous setae on their inner margins.

2.4.3 Time for mating Sexually mature males are able to mate at any time, while the females are ready to respond only after completing their pre-mating moult. Under Malaysian conditions mating occurs throughout the year.

2.4.4 Mating The mating process may be observed by introducing a mature male and a sexually ripe female (3 to 6 hours after the pre-mating moult) into an aquarium tank with clean freshwater.

It takes only a few minutes for the male and female prawns to get accustomed to each other and to the new situation. Soon after that, the male starts its courtship display, lifting its head, raising its body, waving its feelers and raising and extending its long and powerful chelate-legs in am embracing gesture, accompanied by intermittent jerking movements. This display continues for 10 to 20 min before the female is successfully won over.

The male then holds the female between its long chelate-legs and at the same time actively cleans the ventral portion of her thoracic shell with its other legs. It takes about 10 to 15 min to complete this cleaning act, and then follows the final mating act which lasts only a few seconds. The female is placed ventral side up while the male presses down from above, bringing its genital pores in close contact with the cleaned ventral thoracic region of the female, and with a sudden vigorous vibration of the pleopods and trembling of the body the sperm is ejected and deposited in one gelatinous mass on the female's ventral median thoracic region.

When several mature female prawns are kept in the same tank, the one that has just completed her pre-mating moult is liable to be attacked by the others. However, in the presence of a mature male, she would be promptly and tenderly protected by him. It is possible that as soon as the pre-mating moult is completed the female secretes a substance which strongly attracts the males.

2.4.5 Egg-laying Egg-laying takes place between 6 and 20 h after mating, depending on how soon mating follows the pre-mating moult of the female. Unmated ripe female prawns also lay eggs within 24 h of the pre-mating moult, but the eggs are not fertilized and drop off in two or three days. The laying of one whole batch of eggs is usually completed within 20 min.

During egg laying the tail of the female prawn bends forward to reach the ventral thoracic region. At the same time the pleopods are extended to form a protected egg passage. The eggs are then extruded through the female genital pores into the brood chamber, first on one side then the other. The chamber between the 4th pair of pleopods is filled first, then those between the 3rd, 2nd and 1st pairs, successively. The eggs are held in bundles like grapes by an extremely thin elastic membrane which is believed to be secreted by the ovigerous setae. The egg bundles adhere tightly to the ovigerous setae of the first four pairs of pleopods.

3 DEVELOPMENT

3.1 Eggs, embryonic development, and hatching

3.1.1 Eggs and fecundity The eggs are slightly elliptical, of long axis 0.6 to 0.7 mm, bright orange in colour, and each has a thin membrane.

A typical mature female of about 80 g in weight and 18 cm in length can produce about 60,000 eggs, as many as 100,000 eggs may be produced by a large female.

Mature females kept in the laboratory are able to lay eggs twice within five months. It is quite possible, therefore, that they may be able to lay eggs 3 to 4 times in one year under natural conditions.

3.1.2 Incubation The female prawn carries her brood of eggs and takes care of them until they hatch. During the whole incubation period, which is about 19 days at 26 to 28°C, the pleopods beat back and forth intermittently to provide aeration for the eggs. Dead eggs and foreign material are carefully and cleverly removed from time to time by the sensitive and versatile first pair of thoracic legs. Starting from the 12th day of incubation, the bright orange colour of the eggs gradually becomes lighter, and in its place a light grey colour slowly develops. The colour gradually deepens to slate grey by the 16th to 17th day of incubation, when the larvae inside the eggs are fully developed.

3.1.3 Segmentation and embryonic development Material for study was obtained from female prawns mated and spawned in aquaria. Fertilization of eggs is assumed to take place at the time of extrusion. Groups of about 40 to 50 eggs can easily be removed from the brood chamber of a berried prawn for study. With frequent changes of water and cleaning of the eggs, they can be kept alive in an embryo-dish or petri-dish for several days.

Newly fertilized eggs are homogenously granulated. After about 2 h the stellate island of protoplasm containing the nucleus is discernable at the center of the egg and becomes clearly visible about 1 h later.

Counting from the time of fertilization, the first nuclear division starts at about 4 h and is completed within one h; the second nuclear division commences at 6 h and is completed at 7½ h; the third division begins at 8 h and eight nuclei are formed by 9 h. Subsequent divisions take place at about 1 to 1½ h intervals, and segmentation is completed in about 24 h.

Segmentation is illustrated in Fig. 2A-F. The first and second nuclear divisions are completed without any corresponding division of the cell. Four cleavage furrows appear when the third nuclear division is almost completed; they start from four sub-equidistant points on the surface and extend rapidly almost at right angles to each other to form four quadrants, or blastomeres, whose apexes become joined by a median furrow; each of the four quadrants contains two nuclei. The fourth nuclear division is holoblastic. The fifth and subsequent nuclear divisions are superficial. Advanced segmentation stages show distinct hexagonal markings on the surface.

Nuclei of early segmentation stages are located in the deeper part of the egg. Starting from the eight blastomere stage they tend to appear nearer to the surface, and in the advanced stages all of them reach the surface, as in other Decapoda.

During the second day, after the completion of segmentation, the germinal disc appears on the ventral side of the embryo. Gastrulation takes place by the immigration of cells from the posterior part of the germinal disc, which is soon followed by the formation of the blastopore. A V-shaped germinal band is then differentiated from the blastoderm, occupying a large part of the ventral surface, and assuming the position of the developing embryo.

During the third day, the anterior ends of the germinal bands enlarge in size and become circular, representing the prostomial lobes. The rest of the arms of the germinal bands are narrow and are joined posteriorly with the edge of the blastoporal area. The rudiments of embryonic regions are now formed, and the embryo soon develops into the nauplius embryo stage.

The formation of buds of the nauplius appendages starts when the embryo is about 80 h old. The first to appear are the rudiments of the antennules, which appear near the base of the prostomial lobe, and the rudiments of the mandibles near the posterior end of the germinal band. These are followed by the buds of the antennae, on the sides of the germinal band between the antennules and mandibles.

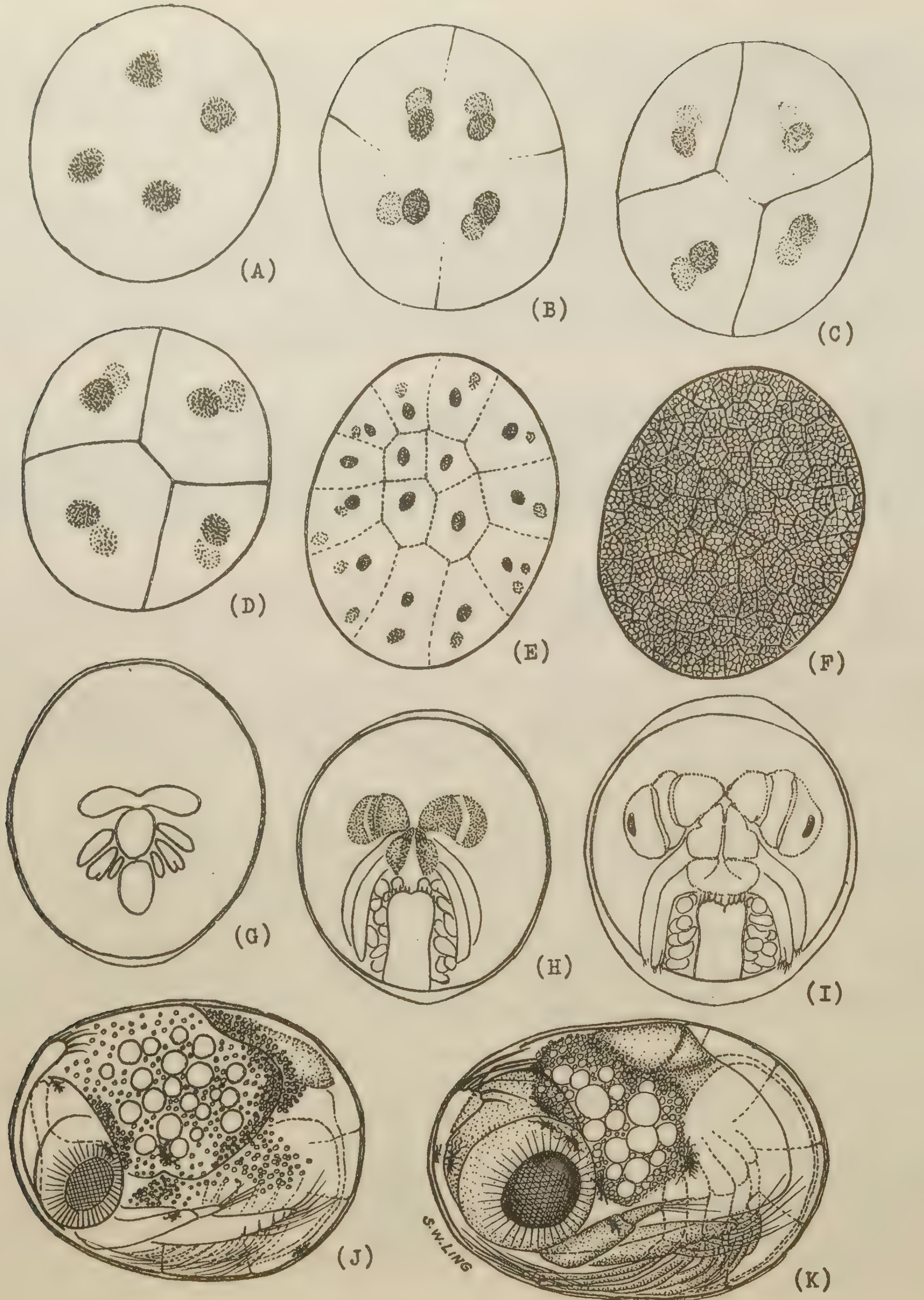


Fig. 2 Macrobrachium rosenbergii, segmentation and embryonic development. Times refer to period since fertilization.
(A) 7 h - completion of second nuclear division. (B) 8 h 45 min - third nuclear division nearly completed, appearance of 4 cleavage furrows. (C) 8 h 55 min - third nuclear division completed, tips of the 4 cleavage furrows have met at 2 points from which the median furrow is developing. (D) 9 h - complete formation of 4 quadrants (blastomeres). (E) 14 h - 32 nuclei. (F) 24 h - completion of segmentation. (G) 6 days - formation of caudal papilla. (H) 7 days - formation of optic vesicle. (I) 9 days - eye pigment developed. (J) 14 days - larva fully formed. (K) 19 days - larva ready to hatch.

By the beginning of the 5th day, when all the rudiments of the nauplius appendages are well formed, post-nauplius segments begin to form, followed by the appearance of rudiments of the other cephalic appendages. At the same time the formation of the caudal papilla commences and becomes very pronounced at the end of the 6th day, with rudiments of thoracic legs and telson formed (Fig. 2G).

During the seventh day, the optic rudiments develop into a pair of large oval masses, forming the optic vescicles. The rudiments of appendages begin to elongate. The forward growth of the caudal papilla becomes conspicuous, and its tip forms the telson (Fig. 2H).

During the 8th and 9th days, the carapace rudiment is formed; the eyes become pigmented, the heart makes its appearance and starts beating, and the gut is formed (Fig. 2I).

When the embryo is 12 days old it comes to lie parallel to the long axis of the egg. The appendages elongate steadily and organs develop and are fully formed by about the 17th day. The larva keeps growing steadily until hatching on the 19th or 20th day (Fig. 2J, K).

3.1.4 Hatching Under laboratory conditions, it takes about 1 h for individual eggs to hatch, about 4 to 6 h for the whole batch.

Hatching is accomplished by the rapidly increasing internal pressure, developed by the increased volume of the larva and aided by the stretching of the body and movements of appendages, causing the egg membrane to burst. The process of hatching starts with a slow but continuous vibration of the mouthparts of the larva, accompanied by some stretching of its rolled-up body, forcing the egg to elongate gradually. Vibration of the mouthparts becomes more and more vigorous, accompanied by churning of the yolk mass, gradually straightening of the spines of the telson and further stretching of the body. About 45 min from the commencement of hatching the thoracic appendages start to vibrate intermittently, and during the next 10 min these periods of activity become more vigorous and more prolonged until the vibration is continuous. The body continues to stretch, and the telson, which is held over the eyes and head, pushes outward. Suddenly the egg shell breaks, and the telson bursts out, followed by the head, and with a forceful flex and stretch of the body the larva springs out of the egg membrane. In less than 5 min the newly hatched larva starts swimming around actively. During the time of hatching the mother prawn vibrates her pleopods rapidly at intervals to disperse the new hatchlings.

3.2 Larvae

3.2.1 General biology of larvae All larval stages are active swimmers and are planktonic in habit. They are attracted by light, but direct sunlight and other strong lights are avoided. They swim tail first, ventral side up, with the head rather lower than the tail at an oblique angle.

Individuals of early larval stages tend to swim close together in large groups, usually close to the surface of the water. Frequently, the thousands of young larvae in each group swim swiftly in a continuous stream, milling and churning up and down repeatedly. The gregarious habit gradually disappears after the larvae are about 10 days old.

All larval stages require brackish water, corresponding to 20 to 40 percent sea water. Specimens reared in pure freshwater all died within 4 to 5 days. Under natural conditions, larvae may hatch in both brackish and fresh water areas, but those that hatch in fresh water would soon be carried by the flow of water to the estuaries, and those that failed to reach brackish waters within 4 to 5 days would be unable to survive.

All larval stages eat continuously as long as suitable food is available. Their natural food consists mainly of zooplankton, including rotifers, cyclops, copepods and

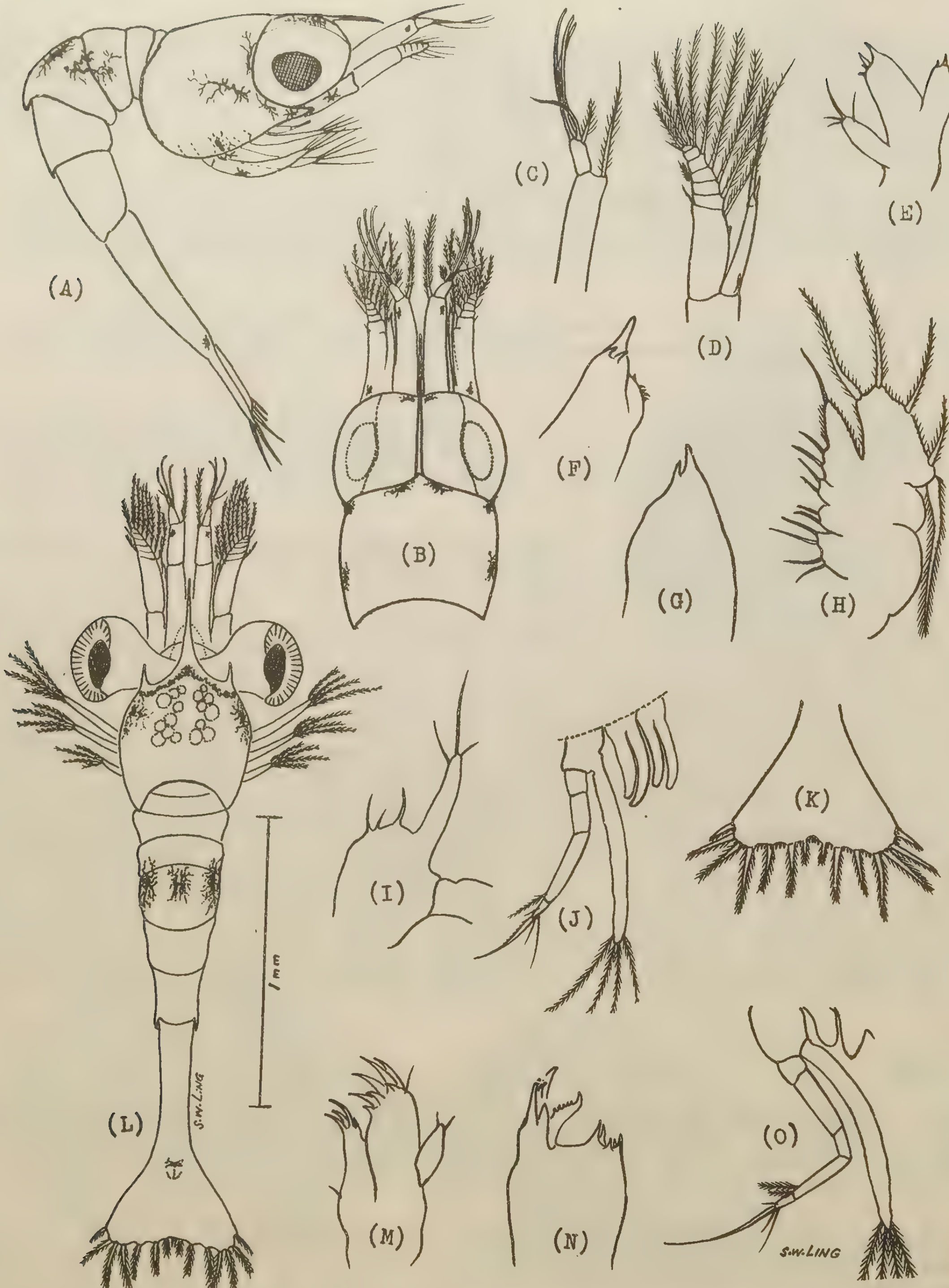


Fig. 3 Macrobrachium rosenbergii, first and second stage larvae.
(A) - (K) First stage: (A) Side view. (B) Dorsal view of head. (C) Antennule. (D) Antenna. (E) Maxillule. (F) Right mandible, distal portion. (G) Left mandible, distal portion. (H) Maxilla. (I) Maxilliped 1, most of exopod omitted. (J) Maxilliped 3, with biramous buds of thoracic legs 1 and 2 shown behind. (K) Telson.

(L) - (O) Second stage: (L) Dorsal view. (M) Maxillule (N) Right mandible, distal portion. (O) Thoracic leg 2, with buds of legs 3 and 4 shown behind.

other minute crustaceans, very small worms and larval stages of various aquatic invertebrates. In the absence of living food, minute pieces of organic material, especially those of animal origin (fish, prawn, crab, mollusc, etc) are readily eaten. Very small particles of plant material, especially those rich in starch (grain, seeds, fruits, nuts, etc) are also taken. Food particles are caught with the maxillepeds and thoracic legs while the larvae are swimming. Living food and suspended particles of suitable size are preferred. Liquid foods are not taken, and extremely small food particles are ignored. Large and heavy food particles tend to drag the feeding larvae with them to the bottom and cause considerable mortality.

3.2.2 Development of larval stages From hatching until metamorphosis into juveniles, the larvae undergo 11 moults, but only eight morphological stages can be recognized distinctly. From the first to the fifth stage, each moult results in a new stage; from the sixth stage to the juvenile stage, two moultings occur between two consecutive morphological stages. For the sake of convenience, these eight stages are described below as the eight larval stages. The growth rate of the larvae is fairly even during the first three larval stages, but then becomes irregular.

First larval stage (1 to 2 days from hatching) (Fig. 3A-K)

Length: 2.0 to 2.2 mm (from tip of rostrum to tip of telson).

Body: transparent, antennular peduncle slightly bluish, eyes light brownish on their outer portion. Chromatophores similar to those of other palaemonid larvae; the 2 pairs on abdominal segment III are very prominent, with dendrites reaching abdominal segment II.

Rostrum: slender, curved slightly downward at tip, reaching to about 2/3 length of basal segment of antennular peduncle. Antereo-ventral margin of carapace produced into small spine.

Eyes: large, sessile.

Antennule: peduncle narrow, long, unsegmented; inner flagellum long, plumose; outer flagellum rectangular, 3 long aesthetes, 1 long seta, 1 short stout plumose seta.

Antenna: peduncle unsegmented; flagellum unsegmented, 1 long and 1 short apical setae; exopod with about 5 annulations in distal half, 9 long plumose setae, 2 short outer setae.

Mandibles: right and left mandibles similar in size and shape; right mandible with 1 large and 2 medium teeth on incisor part, 4 to 5 small spine-like teeth on molar part; left mandible with 2 teeth on incisor part, none on molar part.

Maxillule: very small; palp (endopod) prominent, 2 short spines at apex; proximal lacinia (of masticatory process) about same size as palp, 4 setae at tip; distal lacinia about twice as large as proximal, 2 large and 2 small teeth at distal end.

Maxilla: scale (exopod) with 5 long plumose setae on outer edge, proximal seta largest; endopod with long terminal non-plumose spine, 2 setae on thicker proximal portion; protopod with 3 lobes, proximal with 4 setae, others with 2 setae each.

Maxilliped 1: base almost round, 3 setae on upper margin; endopod finger-shaped, 3 terminal setae; exopod long, 4 long plumose setae at apex.

Maxillipeds 2 and 3: endopod 4-segmented, 1 finely serrated claw and 2 setae at apex; exopod long, 4 long plumose setae at apex.

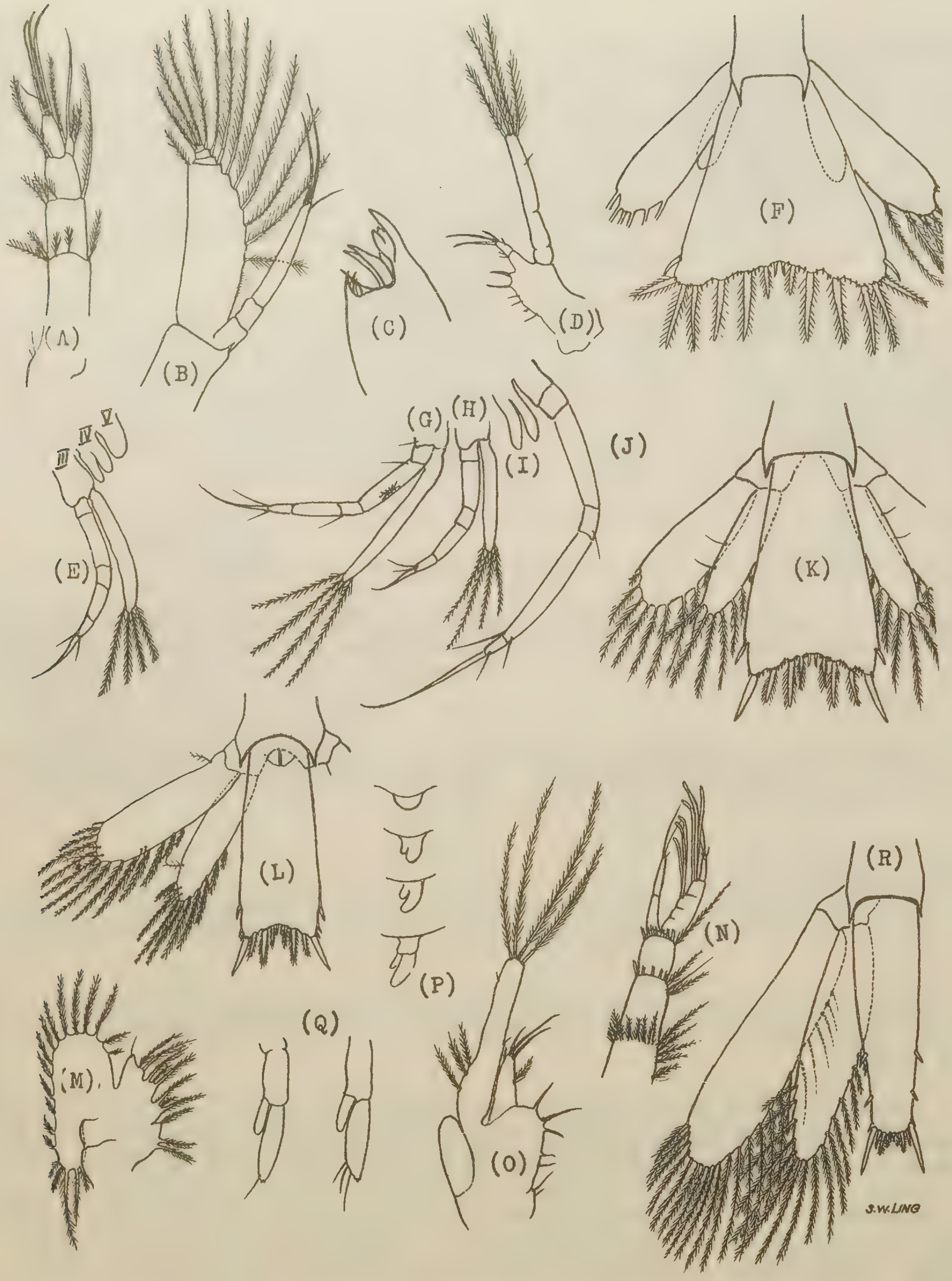


Fig. 4 Macrobrachium rosenbergii, third, fourth, fifth and sixth stage larvae. (A) - (F) Third stage: (A) Antennule. (B) Antenna. (C) Left mandible, distal portion. (D) Maxilliped 1. (E) Thoracic leg 3 with buds of legs 4 and 5. (F) Telson and uropods.

(G) - (K) Fourth stage: (G) Thoracic leg 2. (H) Thoracic leg 3. (I) Thoracic leg 4 in bud form. (J) Thoracic leg 5. (K) Telson and uropods.

(L) Fifth stage: telson and uropod.

(M) - (R) Sixth stage: (M) Maxilla. (N) Antennule. (O) Maxilliped 1. (P) Pleopods in different early stages of formation. (Q) Pleopods in later stages of formation. (R) Telson and uropod.

Thoracic legs 1 and 2: biramous buds.

Telson: triangular; posterior edge broad, slightly concave, notched in middle, 7 pairs stout plumose setae (2 lateral pairs plumose only on inner edge), many small stout spines.

Second larval stage (3 to 5 days from hatching) (Fig. 3L-O)

Length: 2.3 to 2.4 mm.

Prominent red chromatophore with light brown dendrites on ventral side of eye stalk; pale yellow pigment on frontal portion of eyes.

Antero-ventral margins of carapace produced further forward to form the pterygostomian spines. Supraorbital spine very prominent.

Eyes large, stalked. Antennular peduncle 2-segmented. Antennal flagellum carrying 2 long and 1 short setae at apex. Right mandible with 5 stout teeth on incisor part, innermost curved and serrated on upper margin; molar region with 5 short teeth. Left mandible with 3 long teeth on incisor part and 2 short teeth on molar region. Maxillule with 2 short setae at apex of palp; proximal lacinia with 4 long teeth; distal lacinia with 4 long and 3 short teeth. Exopod of maxilla with 7 long plumose setae.

Maxilliped 1: Endopod of maxilliped 1 shorter, with 3 terminal and 2 lateral setae. Thoracic legs 1 and 2 each with large 5-segmented endopod ending in long curved smooth spine; exopods large, setose. Rudimentary buds of legs 3 and 4 present.

Telson bears additional (8th) pair short non-plumose setae at centre of posterior edge.

Third larval stage (5 to 8 days from hatching) (Fig. 4A-F)

Length: 2.7 to 2.8 mm.

One epigastric spine behind base of rostrum. Peduncle of antennule 3-segmented. Antennal flagellum 2-segmented; exopod with 12 to 13 long plumose setae, annulation confined to apex. Exopod of maxilla with 9 plumose setae. Thoracic leg 3 similar to 1 and 2. Buds of thoracic legs 4 and 5 present.

Articulation between 6th abdominal segment and telson. Lateral and central pairs of telson setae (1st and 8th pairs) not plumose. Uropods present; outer lobe more than twice as long as inner, with 6 long plumose setae on distal portion; inner lobe without setae.

Fourth larval stage (8 to 12 days from hatching) (Fig. 4G-K)

Length: 2.9 to 3 mm.

Prominent chromatophore on ventral side of 4th abdominal segment. Distinct red and blue pigment on thoracic leg 2.

Carapace bears two median dorsal (epigastric) spines behind base of rostrum, both spines with 2 to 3 teeth on front edge.

Antennal exopod with 15 to 16 plumose setae and 1 apical spine; no annulations. Thoracic leg 4 a biramous bud. Leg 5 large, segmented, with very long curved terminal spine; no exopod.

Telson much narrower; posterior width less than twice anterior width and only about half length of lateral. Exopod and endopod of uropod articulate with protopod; exopod bears 9 to 10 long plumose setae, endopod 6 to 7 setae.

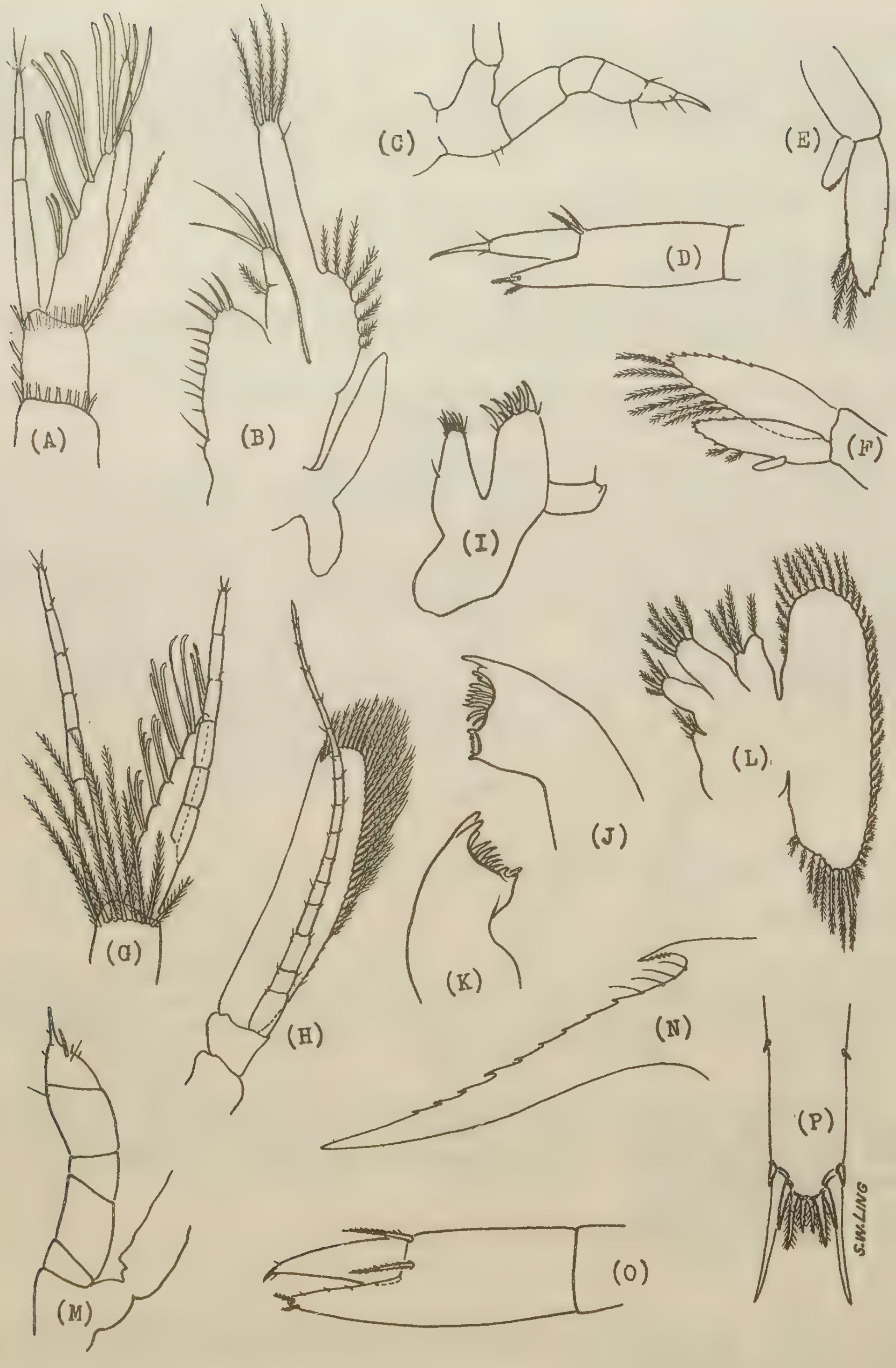


Fig. 5 Macrobrachium rosenbergii, seventh and eighth stage larvae. (A) - (F) Seventh stage: (A) Antennule. (B) Maxilliped 1. (C) Maxilliped 2, most of exopod omitted. (D) Thoracic leg 2, chela. (E) Pleopod 1. (F) Pleopod 2.

(G) - (P) Eighth stage: (G) Antennule. (H) Antenna. (I) Maxillule. (J) Right mandible. (K) Left mandible. (L) Maxilla. (M) Maxilliped 2, most of exopod omitted. (N) Rostrum. (O) Thoracic leg 2, chela. (P) Telson, posterior portion.

Fifth larval stage (11 to 17 days from hatching) (Fig. 4L)

Length: 3.2 to 3.3 mm.

Chromatophore on thoracic leg 2 very prominent, with red centre and blue dendrites.

Epigastric spines each with 4 to 5 teeth.

Proximal end of exopod of maxilla bears 2 long backwardly-directed plumose setae. All 5 pairs thoracic legs segmented; 5th pair longest, remains uniramous.

Telson rectangular, twice as long as broad; 3 pairs lateral setae, 5 pairs on posterior margin; outer 4 pairs and innermost pair smooth, other 3 pairs plumose. Exopod of uropod with 13 to 14 long plumose setae, endopod 9 to 10 setae.

Sixth larval stage (15 to 24 days from hatching) (Fig. 4M-R)

Length: 3.4 to 3.5 mm.

Transparent; pale salmon-pink, deeper at head end and paler towards telson. Chromatophore on ventral eye stalk very prominent, with brownish-red centre and red and yellowish dendrites; chromatophore on thoracic leg 2 remains prominent, with red centre, blue dendrites and some green spots; chromatophore on ventral side of abdominal segment 4 greatly enlarged, with deep blue centre and dendrites of red, blue and yellow.

Inner flagellum of antennule elongated, 3 long setae at apex; outer flagellum segmented, 6 to 7 aesthetes in 2 groups. Antennal flagellum slightly longer than scale. Endopod of maxilliped 2-segmented, 3 long and 1 short spines at apex. Pleopod buds on abdominal segments 1 to 5; differences in development from specimen to specimen; 2nd, 3rd and 4th pairs usually more advanced; larger buds biramous.

Telson much elongated; posterior width only about 2/3 anterior width and about 1/5 length; marginal spines and setae smooth, apart from 2 pairs next to central pair. Uropod with 12 to 16 plumose setae on endopod, 16 to 20 on exopod.

Seventh larval stage (22 to 32 days from hatching) (Fig. 5A-F)

Length: 4.0 to 4.5 mm.

Inner flagellum of antennule 3-segmented; outer flagellum split longitudinally: inner part faintly segmented, with 10 to 11 aesthetes in 4 groups; outer part longer, forms flagellum proper. Thoracic legs 1 and 2 chelate. All 5 pairs pleopods biramous, exopod and endopod both with plumose setae.

Telson narrower and longer; 3 pairs short lateral setae, 4 posterior pairs; inner 2 pairs plumose.

Eighth (last) larval stage (30 to 45 days from hatching) (Fig. 5G-P)

Length: 5.0 to 5.8 mm.

Rostrum with 4 to 9 teeth on upper margin, 4 short plumose setae between front epigastric spine and hind rostrum tooth.

Inner flagellum of antennule 5 to 6 segmented; shorter outer flagellum with 14 to 15 aesthetes in 6 groups; longer outer flagellum 6 to 8 segmented. Antennal flagellum many segmented, about 1 1/2 times as long as scale.

Left mandible with 3 large teeth and 5 to 6 slender ones on incisor part, 3 to 4 short teeth on molar area. Right mandible with 2 big blunt teeth and 8 to 10

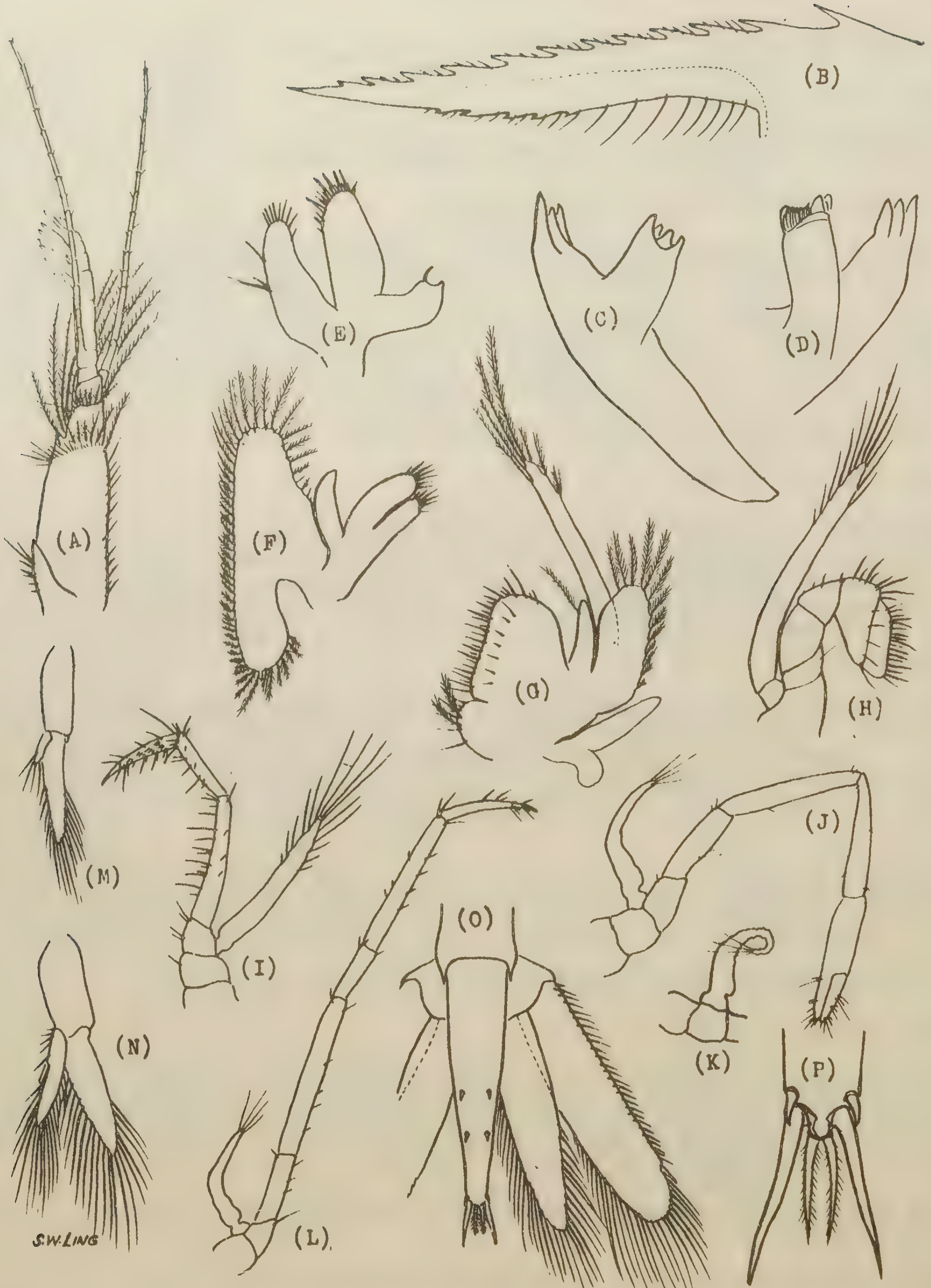


Fig. 6 Macrobrachium rosenbergii, first juvenile stage.
(A) Antennule. (B) Rostrum. (C) Right mandible. (D) Left mandible.
(E) Maxillule. (F) Maxilla. (G) Maxilliped 1. (H) Maxilliped 2.
(I) Maxilliped 3. (J) Thoracic leg 1, with degenerating exopod.
(K) Thoracic leg 2, basal portion with degenerating exopod.
(L) Thoracic leg 4. (M) Pleopod 1. (N) Pleopod 4. (O) Telson and uropod. (P) Telson, posterior portion.

long slender ones on incisor area, molar region with 2 stout and 4 short teeth. Palp of maxillule with only 1 seta and small protuberance at tip; proximal lacinia with 8 to 10 fine setae at apex, distal lacinia with 7 to 8 long and 3 to 4 short teeth. Scale of maxilla with about 50 plumose marginal setae; distal and median lobes of protopod well developed, finger shaped, with both plumose setae and spines; proximal lobe reduced. Basal endite of maxilliped 1 with many slender spines; endopod 3-segmented; exopod with 10 plumose setae on the outer edge of the enlarged basal half. Endopod of maxilliped 2 finger-shaped, 5-segmented, with 2 stout spines, 1 terminal and 1 subterminal. Thoracic leg 2 the largest.

Telson very much elongated; posterior portion narrow, with 5 pairs spines on posterior edge, the inner 2 pairs plumose.

3.3 Juveniles

3.3.1 General habits Juveniles cease to be permanently pelagic as soon as they metamorphose from the last stage larvae. They settle to the bottom as crawlers or cling to vegetation and submerged objects. They feed readily on tiny worms, small crustaceans, insect larvae and a large variety of small pieces of organic material, both of plant and animal origin. They grow rapidly, moult every 5 to 10 days, and are able to attain a length of about 5 cm in 2 mo.

Under natural conditions, newly transformed juveniles usually remain in brackish water areas for a week or two then start migrating slowly upstream into water of lesser salinity. When they are about 1 mo old they are able to migrate quite fast. After 2 mo they are able to swim against swift currents or cross rapids by crawling. They will climb over bunds or dams 2 to 3 m high, provided there is a little water dripping over the dam. During the rainy season they are capable of migrating through temporary shallow streamlets into ponds, pools, padi-fields and other types of water which are normally inaccessible to them during the dry season. The fact that adults have occasionally been caught in waters over 200 km away from brackish water areas indicates the great distance they are able to cover.

3.3.2 Characteristics of newly transformed juveniles (Fig. 6)

Length: from tip of rostrum to tip of telson, 6.0 to 6.5 mm; from tip of antennal scale to tip of telson, 6.0 to 6.6 mm.

Translucent; light orange-pink in head end, lighter toward abdomen and telson; brown chromatophores at base of eyes and front of carapace; red on sides and hind part of carapace, on sides of first 5 abdominal segments and at bases of uropods; orange and red pigment along ventral side of abdominal segments 2, 3 and 4, joining large conspicuous red and blue chromatophore at ventral side of abdominal segment 4.

Rostrum lancet-shaped; 11 teeth above, 3 to 5 below, fine plumose setae in spaces between teeth.

Inner flagellum of antennule 14 to 16-segmented; longer outer flagellum 13 to 15-segmented; about 16 aesthetes in 6 groups. Antennal flagellum about 3 times length of scale. Incisor and molar parts of mandible distinctly separated, forming a "V" shaped structure on a long base. Incisor part of each mandible with 3 large teeth; molar part of right with 4 short blunt teeth; molar part of left with 1 pair of blunt teeth, 2 to 3 small teeth at outer corner and large molar surface surrounded by many slender teeth. Maxillule similar to that of last larval stage. Maxilla with distal and median lobes of protopod elongated, with many fine apical setae; proximal lobe disappeared. Maxilliped 1 foliaceous: 2 large setose endites; large setose outer lobe at base of exopod. Endopod of maxilliped 2, 5-segmented, the 2 distal segments with spines and setae. Endopod of maxilliped 3, 4-segmented, setae in rows on terminal segment; exopod with 4 long apical plumose setae and shorter lateral setae. Second pair of legs the largest; degenerating exopods on legs 1 to 4 become reduced to knobs at next moult.

Only 2 pairs of spines on posterior edge of telson, inner pair plumose; anterior 2 pairs of spines (previously lateral) now dorsal.

Practical methods for rearing and culturing M. rosenbergii on a large scale are described by Ling (in press).

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METHODS OF REARING AND CULTURING Macrobrachium rosenbergii (DE MAN)[1]

by

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Abstract

Practical methods are given for culturing and farming *M. rosenbergii* on a large scale. Suitable water conditions, food, tanks, ponds, buildings and equipment for all stages are specified. The scheme covers rearing to early juvenile stages under hatchery conditions and the subsequent stocking of ponds and padi-fields.

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[1] An FAO/Malaysian Research Project, conducted at the Fisheries Research Institute, Glugor, Penang, Malaysia.

E/31

METHODES D'ELEVAGE DE
Macrobrachium rosenbergii (DE MAN)

Résumé

La communication décrit des méthodes pratiques d'élevage de M. rosenbergii à grande échelle. Elle indique les caractéristiques auxquelles doivent satisfaire l'eau, l'alimentation, les réservoirs, étangs, constructions et matériels requis à tous les stades des opérations. Celles-ci vont de l'élevage en "pouponnières" jusqu'aux premiers stades juvéniles à l'immersion en étanges et rizières.

METODOS DE CRIA Y CULTIVO DE
Macrobrachium rosenbergii (DE MAN)

Extracto

Explica el autor métodos prácticos para el cultivo y cría de M. rosenbergii en gran escala. Detalla las condiciones convenientes del agua, alimento, tanques, estanques, edificios y equipo para todas las fases. El plan comprende la cría en piscifactoría hasta las fases juveniles y su traslado posterior a los estanques y arrozales.

1 COLLECTION AND TRANSPORT OF SPECIMENS OF *Macrobrachium rosenbergii*

Young and mature prawns suitable for culturing and breeding purposes may be collected from rivers, lakes or other natural habitats, with trap, line and hand-net.

Traps made of bamboo splits or galvanized wire netting, baited with coconut, fish or prawn, are set near the bank in the afternoon, and the catch is removed early in the morning. Mesh size is determined by the size of specimens expected.

Brush traps (large bundles of branches), set near river banks, are often effective in attracting fairly large numbers of young prawns. In places where the water is less than 10 ft deep and the bottom is fairly free from logs and stones, a cast-net can be used.

Ordinary nylon line with a barbless hook or hooks is commonly used in both Malaysia and Thailand for catching this prawn from rivers. Earthworms, small shrimps and small pieces of baked coconut are some of the favourite baits used. A small sinker is tied about one foot above the hooks, and the baited hooks are allowed to lie on the bottom. When a bite is detected, a few seconds must be allowed for the prawn to hold fast to the bait and hook; the line is then drawn up steadily, without jerking. Specimens caught are kept temporarily in submerged wire cages to ensure their healthy condition.

At night, prawns tend to move into shallow water to feed. When the water is clear a strong torch will reveal the characteristic bright pinkish reflection of their eyes, and specimens momentarily stupified by the bright light can be caught with a hand-net drawn from tail to head.

Young prawns are often present in considerable numbers below dams. At night, many of them will climb up and cling to the wet wall, and they can be collected with a simple hand-net.

Living specimens can be transported for a considerable distance in large tanks provided with aeration or continuous water circulation. For long journeys, specimens can be transported in plastic bags with oxygen, provided that the sharp tip of the rostrum of the larger specimens is cut off to prevent puncturing the bag. Prawns can be safely carried for three or four hours in shallow open fish containers, with water just deep enough to cover the specimens. They will also survive for several hours in bamboo baskets, packed between layers of moistened moss or soft aquatic plants, provided that small amounts of water are sprinkled into the basket at frequent intervals.

2 CONDITIONS FOR MATING, SPAWNING AND HATCHING

When berried females are not available from natural sources, spawning under controlled conditions becomes necessary. One pair will spawn in an aquarium of about 60 l capacity, while group spawning requires a large tank or trough.

Mature healthy males are kept separately, one in each tank. Several mature females may be kept together in one large tank, but every newly moulted ripe female should be promptly screened off from the rest to prevent it from being attacked while her new shell is still soft. Two or 3 h after moulting, when the new shell is fairly hardened, she is introduced into one of the male tanks. Mating will take place within a few hours, followed by egg-laying within 24 h.

For group spawning, a tank of about 1 m x 2 m and 40 cm high can hold about 10 specimens, and a trough of 1½ m x 3 m and 40 cm high about 24 specimens. One male to 4 to 5 females is a good ratio for spawning purposes. Newly-moulted sexually-ripe females are promptly attended by the males present, and mating and egg-laying take place without trouble.

All the spawning tanks and troughs should be provided with efficient aerators. A few days after egg-laying, the berried females should be transferred into hatching tanks.

Berried females, either collected from their natural habitats or mated and spawned in the hatchery, should be kept separately, one in each tank of about 50 to 60 l. During the whole incubation period the water of the hatching tank should be kept clean and well aerated.

As soon as the colour of the eggs starts changing from bright orange to light grey, it is advisable to add enough seawater gradually to the tank to raise the concentration to about 5 percent seawater. Although eggs will hatch well in freshwater, the presence of a small amount of seawater seems to provide a better medium for hatching and for the new hatchlings to live in.

3 REARING OF LARVAL STAGES

3.1 Facilities and equipment

For experimental purposes, aquaria, ordinary plastic basins and shallow earthenware pots serve well as containers for rearing larvae. Aquaria of about 60 l capacity, basins of about 30 cm in diameter and pots of about 60 cm are convenient sizes.

For large scale rearing of larvae, cement troughs, 50 to 70 cm x 2 to 3 m and 25 cm high are suitable. The bottom should slope slightly and end in a shallow collecting pit at the deeper end (water outlet end). Twin troughs are more economical to construct than single ones.

Sets of 4 cup-shaped strainers, made of nylon, silk or stainless steel, of different mesh sizes ranging from 25 per cm to 7 per cm, are required for the preparation of food for the different larval stages. Strainers of 12 to 14 cm in diameter are convenient.

Air compressor, pipes, air stones, water agitators, hydrometer, siphons, hand-nets, rubber tubing and other general aquarium equipment are also required.

Freshwater from rivers, streams, lakes and ponds should be filtered before using. Tap water (city water), which is usually highly chlorinated, should be seasoned for 3 to 4 days before use.

Seawater may be collected at high tide and should be filtered before using.

It has been found that artificial seawater prepared from rock salt (crude salt) is unsuitable, but that reconstituted from whole salt (evaporated from filtered seawater) works fairly well.

3.2 Living and prepared foods for larvae

Minute zooplankton, such as cyclops, copepods and other small entomostracans can be collected with a fine-meshed conical net. Nauplii of Artemia can be hatched from the egg very easily in 30 to 40 percent seawater in trays or basins. Young Artemia can also be reared in tanks and pots as food for late stage larvae.

Of the various organic materials that are suitable for making into larval food, flesh of fish and shell-fish, steamed egg custard, fish-balls and fish eggs have been found to be the most practical. They are easily available and particles of suitable size can be prepared without difficulty. Flesh of fish is first chopped finely with a heavy kitchen knife, or broken up by passing through a meat grinder, then washed with several changes of clean water to remove soluble matter. The food particles are then graded by passing them through strainers of different mesh-size.

Steamed egg custard is prepared by beating together the yolk and white of hen's egg, a little water is added, then it is cooked in a double-boiler at a low temperature. Small amounts of yeast powder, vitamins or any other substance can easily be mixed with the egg material before it is cooked. The steamed egg is then broken up into small pieces and graded with the strainers into different sizes as above.

Fish balls are made by pounding fish flesh very thoroughly into a paste, which is then made into a small ball and cooked. It is available from the local markets and can be made into particles of different sizes by the method described above. Fish balls are convenient and economical to use, and contain very little soluble matter.

Fresh ripe fish eggs are also well liked by the prawn larvae. Fish roes are frequently available from the local food markets. Ripe eggs can be separated from the ovarian tissue in a bowl or basin with clean water. The eggs are then washed with several changes of clean water before using. Very small eggs are suitable for early larvae and larger ones for more advanced stages.

3.3 Technique and rearing procedure

There is seldom any problem in hatching the eggs if the berried female is kept undisturbed in well aerated water, and, normally, the larvae pass through their first and second stages with little loss. To rear Macrobrachium through all its larval stages, however, requires careful attention to correct feeding, and immaculate cleanliness is necessary to maintain optimum water conditions and to avoid the introduction of enemies and disease.

It has been observed that newly hatched larvae are highly euryhaline and can tolerate a wide range of salinity, but larvae show signs of distress from sudden increase or decrease in salinity. When transferred directly from the hatching tank to water of higher salinity (up to 50 percent sea water) they appear to be highly irritated for a minute or two but soon recover without marked after-effect. The following procedure of transfer of larvae from hatching tank to rearing trough has been found to work well.

The larvae are transferred soon after the whole batch of eggs has hatched. They are induced to concentrate at one end of the hatching tank by shading the rest of the tank with dark cloth or paper. Many of the larvae can then be taken out with a dipper or cup, and the remainder are siphoned out. These are then added slowly and gently to a clean rearing trough, filled to about 2/3 its final level with water of salinity similar to that of the hatching tank (about $1.7^{o}/_{oo}$). A measured amount of filtered sea water is put into a bucket hung above the trough and slowly siphoned into the trough through small-bore rubber tubing, until a salinity of about $12^{o}/_{oo}$ (approx. 35 percent sea water) is reached.

The water in the rearing troughs should be maintained at a salinity of 12 to $14^{o}/oo$ (about 35 to 40 percent sea water), a temperature of 24 to 30°C (optimum range 26 to 28°C) and a pH of 7.0 to 8.0. An aerator and a stirrer keep the water in constant motion and almost saturated with oxygen. The depth of water is 16 to 20 cm.

To avoid pollution, unfinished food particles, larval faecal waste and other undesirable substances that settle to the bottom should be removed by siphoning twice a day.

A partial change of water may be made by concentrating the larvae in one part of the tank or trough by shading the other parts. Water is then siphoned from the shaded part and replaced by new water of the proper salinity. When a complete change of water is required, the larvae are concentrated as before and removed to plastic basins. They are put back again when the rearing tank has been drained, cleaned and refilled with new water.

When a rearing trough is well managed no complete change of water is necessary throughout the entire rearing period, but a partial change is desirable at about 10-day intervals.

3.4 Feeding

Artemia eggs can be hatched in separate basins, but for large-scale operations it is more convenient to hatch them in the rearing troughs. The Artemia eggs are placed in a hatching ring at the shaded end of the trough; hatched nauplii are attracted to the unshaded part where the prawn larvae are present, and the egg shells remaining in the ring can be removed easily. Artemia eggs should be placed in the hatching ring every day from the time of transference of the prawn larvae, so that nauplii are available as food from the second day until the larvae metamorphose. The quantity of Artemia eggs needed for a trough of about 60,000 larvae is approximately 1/3 teaspoonful daily for the first 3 to 4 days, gradually increasing to about 1½ teaspoonfuls per day when the larvae are 30 days old.

For prepared foods, freshness of material and cleanliness in its preparation are important. A new supply of steamed egg custard should be prepared every day. Particle size is important; food particles that pass through a strainer of 25 meshes per cm are suitable for larvae of 2 to 4 days, 20 meshes per cm for larvae of 5 to 10 days, 12 meshes per cm for larvae of 11 to 20 days, and 7 meshes per cm for larvae of over 20 days.

Feeding with prepared food can be started when the larvae are 2 to 3 days old and continued until their metamorphosis. The frequency of feeding is 3 times a day for the first 5 days, 4 times a day during the next 10 days, and 4 times a day plus once at night for the remaining period.

For convenience in feeding it is better to concentrate the larvae at one end of the rearing trough by shading. Food is then gently spread on the surface of the water with a medicine dropper. The action of aeration and the flow created by the water agitator help to keep the light food particles in suspension long enough for the larvae to catch them.

The amount of prepared food to use daily is approximately 30 percent of the total body weight of the larvae. During each feeding the practice is to add food slowly until most of the larvae are seen carrying food; after about 1 min a little more is added to ensure that every larva is fed. Sometimes a little additional food is added between two regular feedings.

3.5 Care of larvae

It has been observed that the larvae suffer considerably if the salinity is suddenly lowered. It is therefore important that the salinity of the rearing troughs should not fall below the desired level. The troughs should be protected from rain. Larvae should also be protected against exposure to direct sunlight and strong illumination.

Prawn larvae are sensitive to nicotine, smoking in the hatchery should therefore be prohibited.

Some Artemia nauplii should be maintained in the rearing trough all the time to avoid cannibalism due to hunger.

Late larvae often jump out of the water and may get stranded on the walls of the trough above the waterline. This stranding may be prevented by shading the sides of the rearing trough, to attract the larvae to the centre, and by the provision of a "deflector" (developed by the Hawaii Division of Fish and Game) which consists of a single strip of plastic mosquito screen, about 12 cm wide, glued to the walls of the rearing tank just below the waterline.

When larvae are ready to metamorphose it is necessary to place small branches, sticks or small stones at the bottom of the rearing trough for the juveniles to settle on and hide in.

3.6 Diseases and parasites

A fungal infection, resulting in very heavy mortality, may occur from time to time. Effective curative measures are still under development. It can be prevented by thorough cleaning and disinfection of all troughs and equipment, careful filtering of water before use, cleanliness in the preparation of food and avoidance of all possible sources of contamination. Infected larvae can be recognized by the presence of small opaque whitish patches, first at the tail and bases of appendages, then spreading to the whole body. Infected larvae should be removed and destroyed. If a large percentage of the larvae in a trough have been infected then it is better to sacrifice them all.

Serious protozoan infection may also sometimes occur. Once the infection starts it may spread very rapidly and cause high mortality. Treatment with malachite green (0.2 ppm for 1/2 h daily), formalin solution (200 ppm for 1/2 h daily) and copper sulphate (0.4 ppm for 6 h, for severe cases repeat at 24 h intervals) have been recommended by Fujimura (1966).

4. REARING OF JUVENILES

4.1 Acclimatization to freshwater

When about 90 percent of the larvae have metamorphosed into juveniles, the remaining slower growers are transferred to another tank for further rearing and the juveniles are ready for acclimatization to freshwater.

When larvae are reared in an aquarium, basin or pot, a convenient way to acclimatize the juveniles is as follows: (1) siphon out about half of the water in the rearing container, (2) introduce freshwater slowly up to the original water level, (3) repeat the process 3 to 4 times at about 1 1/2 h intervals (4) finally, drain the container almost completely and immediately let in freshwater to the desired depth. The whole process can be completed in 6 to 8 h.

When the larvae have been reared in a cement trough, the following acclimatization procedure for juveniles is adopted: (1) screen the water-outlet with fine-meshed nylon material, (2) introduce freshwater into the trough, close to the bottom, slowly but steadily, (3) when the water is almost entirely fresh, the juveniles may be transferred to juvenile rearing ponds. This process can be completed in 3 to 4 h.

4.2 Food and feeding

Suitable food for juveniles includes (1) living aquatic animals: small aquatic worms (Oligochaeta) and insect larvae (Chironomidae), (2) dried animal material: aquatic worms, earthworms, small crustaceans and insects, (3) fresh animal material: small pieces of earthworm, clams, snails, squids, shrimps and fish, (4) plant material: broken rice (unpolished) and other common grains, peas and beans.

Fresh animal material constitutes the principal food. Fresh fish, molluscs and earthworms need to be cut into small pieces, according to the size of the juvenile, and be given three times during the day and once at night.

Dried animal material is used to supplement the fresh diet. It is soaked in freshwater for about half an hour before use. Large pieces are cut into appropriate sizes. This food is given 2 to 3 times a week.

Living aquatic worms and chironomid larvae, when available, are given once a day, preferably in the evening.

Plant material is also used as supplementary food. Grains, peas, beans and soft aquatic plants are broken into small pieces when necessary and are given once every two days.

4.3 Management and care

Juveniles can be reared in the same trough as the larvae, provided they are not too crowded. However, for mass production, it is better to transfer them to juvenile rearing ponds (drainable mud ponds with cemented brick walls). A juvenile pond of about 5 m x 10 m x 40 cm high will accommodate about 10,000 juveniles. The water should be kept well oxygenated by aeration, and, if possible, a slow flow of water should be maintained. The water level should be maintained at a depth of about 15 cm. Pond water should be kept clean and all uneaten food should be siphoned out if possible.

Juveniles are vulnerable to attack by other juveniles during and immediately after moulting. Provision of small branches, gravel and large shells at the bottom of the rearing pond has been found to prevent high mortality from this cause. To minimize cannibalism, juveniles should be well fed, and small quantities of living aquatic oligochaets or chironomid larvae may be given from time to time in addition to those prescribed for regular feeding.

To prevent disease and parasitic infections, the rearing ponds should be completely drained, dried and disinfected before and after use. Methods of prevention and control of disease and parasites prescribed for larval stages (see section 3.6) are applicable here.

With good management and feeding juveniles are able to grow to young prawns of about 5 cm in the rearing pond within 60 days.

5 HATCHERY PLAN

To set up and operate a hatchery to produce annually about 1 million young M. rosenbergii for stocking and culturing, the essential requirements are as follows:

5.1 Stock of mature prawns

Ten to 12 good berried females will be needed every month. In places where berried females are easily available from their natural habitats they should be collected at regular weekly intervals. Alternately, a stock of about 60 mature females and 12 males should be maintained in the hatchery. From this stock 10 to 12 females may be expected to breed every month. To ensure spawning efficiency, females should be discarded and replaced after their second spawning in the hatchery, and males should be replaced every three or four months.

5.2 Ponds and tanks

For maintaining the above breeding stock, three cement ponds, each measuring about 1½ m x 3 m x 40 cm deep, will be needed. Four aquaria, each measuring about 40 cm x 80 cm x 60 cm high, will be required as spawning tanks. A series of 16 to 20 aquaria, each of about 60 l capacity, about 30 cm x 60 cm x 35 cm high, will be needed as hatching tanks.

Ten sets of twin cement troughs, each measuring about 70 cm x 3 m x 25 cm high, will be required for larval rearing. Each trough can accommodate all the larvae (about 60,000) produced by one female at one hatching, and the same trough can be used for rearing 6 batches of larvae per year. Each batch is expected to produce on average about 10,000 juveniles.

For rearing juveniles, 20 ponds (brick walls and mud bottom), each measuring 5 m x 10 m x 40 cm high, are recommended. Each pond will take 6 batches of juveniles a year, each batch consisting of about 10,000 specimens.

5.3 Aeration and stirring systems

A reliable air-compressor, capable of supplying filtered air to all tanks and troughs at about 5 lb/in^2 (360 g/cm^2) pressure, together with the necessary pipes and lines, valves, air-stones and other accessories, is essential equipment that must be maintained in good condition all the time. A second air-compressor should also be installed as a standby. In addition to the air-compressor, about 6 aquarium aerators will be needed from time to time.

Each trough for larvae must be provided with a small water agitator to keep the water in constant motion.

5.4 Other hatchery equipment

A large refrigerator is required for holding a reserve supply of food.

Other items of equipment include hydrometers, salinity meter, pH meter, compressed oxygen cylinder, water analysis equipment, students' dissecting sets, a laboratory microscope, a binocular dissecting microscope, glass ware and a cooker.

5.5 Food

Approximately 5 gallons of brine shrimp (Artemia) eggs will be needed annually. These should preferably be vacuum packed in 1 gallon tins.

Supplies of local materials (fresh fish, eggs, etc) should be renewed at regular intervals to ensure their freshness.

5.6 Water supply system

Two water reservoirs, one for seawater and the other for freshwater, will be needed. The reservoirs should be not less than 1 m above the aquaria and rearing troughs, to ensure good gravity flow.

Different types of water pump, hose and pipelines are needed for seawater and freshwater. Four simple water filters (gravel/sand/charcoal filter) will be needed for filtering seawater and freshwater separately, before and after storage in reservoirs.

5.7 Staff

The staff required would consist of a manager, one trained technician, and four skilled labourers.

5.8 Hatchery building

One building, about 9 m x 24 m, will house the aquaria for spawning and hatching of eggs, the breeding-stock ponds, the larval rearing troughs, air-compressor, refrigerator, work benches and tool stores.

A simple building, with the main parts of the walls made of strong metal screens, will be suitable for the purpose. A suggested floor plan is given in Fig. 1.

The juvenile rearing ponds would occupy a space of about 25 m x 35 m. These should be protected from rain and direct sunlight, but need not be totally enclosed.

6 CULTURING OF YOUNG PRAWNS TO ADULTS

Prawns about two months after metamorphosis, measuring about 5 cm from tip of rostrum to tip of telson, are suitable for culturing. Young prawns collected from their natural habitats are quite suitable for culturing, but their supply is seldom dependable. A constant supply in large numbers can usually only be obtained by rearing them from the larvae.

Young M. rosenbergii are able to live well in varied types of fresh and slightly brackish water, provided that it is fairly well oxygenated and is within the temperature range of 22 to 32°C. They can be cultured in ponds, mining pools, partitioned canals and irrigated padi-fields.

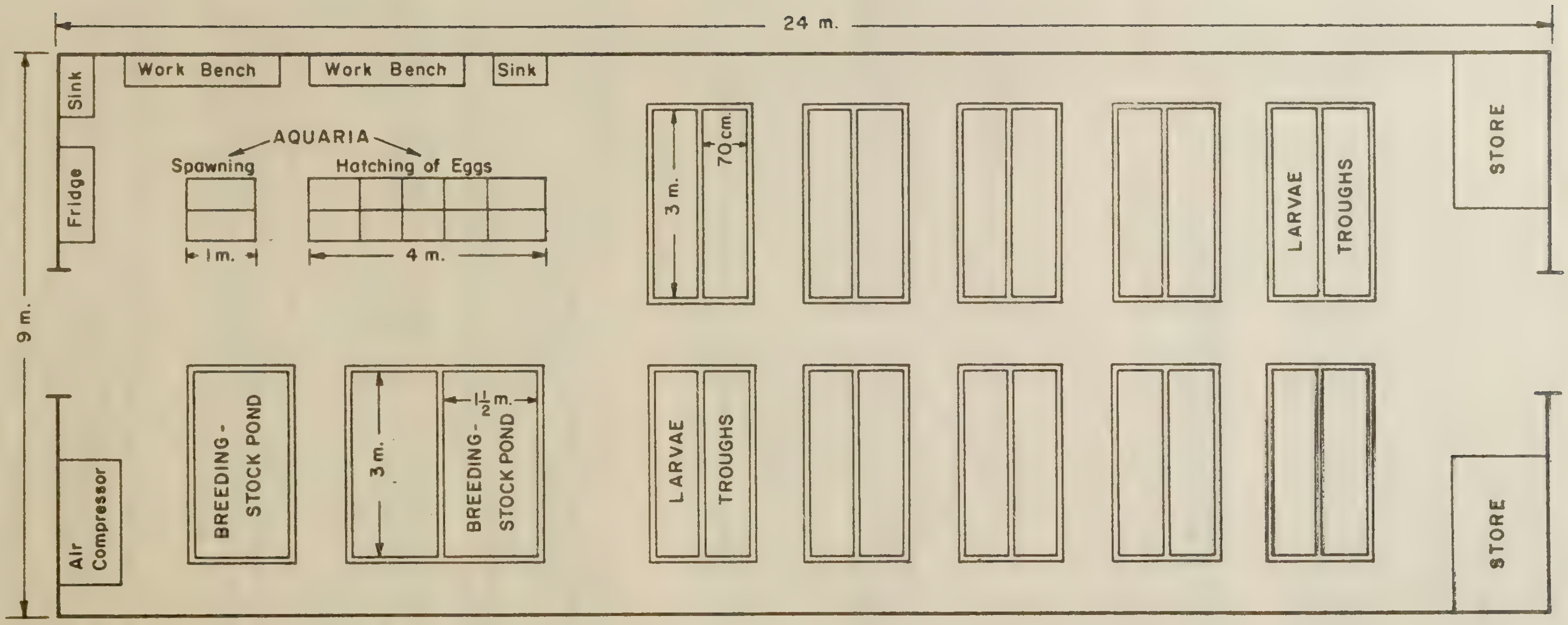
24 m.
9 m.
Sink
Fridge
Work Bench
Work Bench
Sink
AQUARIA
Spawning
Hatching of Eggs
1 m.
4 m.
3 m.
70 cm.
LARVAE
TROUGHS
STORE
Air Compressor
BREEDING - STOCK POND
3 m.
$1\frac{1}{2}$ m.
BREEDING - STOCK POND
LARVAE
TROUGHS
STORE

Fig. 1 Suggested floor plan for a Macrobrachium prawn hatchery.

6.1 Culturing in ponds

6.1.1 *Ponds* Fish-ponds, or any pool of not less than 400 m^2 and over 50 cm in depth, can be used for culturing this prawn, but ponds of over 1,000 m^2 and 1 to 1½ m in depth are more suitable and economical to operate.

In the preparation of ponds and pools for culturing prawns, the routine practice developed for culturing fish, including the installation of screened water inlets and outlets, eradication of predators, removal of excessive growth of aquatic plants, should be followed. It is desirable to have a gentle flow of water, either continuously or for a few hours daily, throughout the entire period of culturing.

Application of animal manure, such as cow dung, mixed with lime, is to be done monthly to promote growth of natural food. About 200 kg of cow dung mixed with 10 kg of lime will be sufficient for each ha of pond of medium fertility, each month.

6.1.2 *Combination with fish* This prawn may be cultured alone or in combination with suitable species of fish; the latter has proved to be more economical to operate. Fish suitable for this purpose are plant and plankton feeders, such as *Hypophthalmichthys molitrix* (silver carp), *Aristichthys nobilis* (big-head carp) *Ctenopharyngodon idellus* (grass carp), *Catla catla*, *Labeo rohita*, *Trichogaster pectoralis*, *Trichogaster trichopterus*, *Puntius gonionotus*, *Mugil cephalus*, *Helostoma temmincki*, *Chanos chanos* and *Osteochilus hasselti*. Food competitors such as *Cyprinus carpio*, *Cirrhina* spp, *Pangasius* spp, *Carassius* spp, are not suitable. Carnivorous or predatory species such as *Ophiocephalus* spp, *Anguilla* spp, *Oxyeleotrix* and *Clarias* should be strictly avoided.

6.1.3 *Stocking rate* The stocking rate for this prawn depends on the richness of the soil, conditions of water and also the kinds and numbers of fish expected to be cultured together. The following tables will serve as a general guide.

Prawns cultured alone

Pond conditions	Stocking rate (prawns/ha)
Rich	15,000
Medium	10,000
Poor	6,000

Prawns cultured in combination with fish

Pond conditions	Stocking rate of fish	Stocking rate (prawns/ha)
Rich	Full	5,000
	Half	8,000
Medium	Full	3,000
	Half	5,000
Poor	Full	1,500
	Half	3,500

6.1.4 Food and feeding Small pieces of waste fish, molluscs, earthworms, offal of animals and fish, insects, silkworm pupae, broken rice, grains, spoiled padi and discarded fruits are all suitable as food. A diet consisting of about 75 percent animal material and 25 percent plant material is suitable as a daily supplement to foods which occur naturally in ponds. In a well fertilized and well managed pond, the natural food material produced in the pond constitutes the main source of food for the prawns, especially during the first 1 to 2 months of culturing. A daily supplement equal to approximately 5 percent of the total body weight of the prawns is sufficient. Half of this should be added in the morning and half in the late afternoon. It may be cast into the pond or placed in shallow feeding trays set along the sides of the pond.

6.1.5 Management and care Water inlets should be carefully screened to prevent the entry of young stages and eggs of predatory fish, and to retain the prawns. For the same reasons, the bunds of the pond should be inspected at frequent intervals and all breakages should be promptly repaired, especially during the rainy season.

Small patches of Ipomoea may be grown in the pond to provide shade and shelter for the prawns, as well as supplying some fodder for the animals and green vegetable for the culturists. However, the area occupied by the Ipomoea should not be more than one tenth of the total area of the pond. In shallow ponds, provision of branches of bamboo or woody plants at the bottom of the pond helps in providing shelter and hiding places for the prawns, especially during their moulting periods, and thus reduces the chance of cannibalism.

Heavy mortality of prawns may occur due to depletion of dissolved oxygen during the hot season, especially in rich and heavily stocked ponds. Prawns suffering from lack of oxygen tend to migrate to the edges of the pond, become progressively weakened and sluggish in movement and die if not rescued in time. Methods used for the prevention and control of mortality due to oxygen depletion in pond fish culture are applicable here. Since prawns are more susceptible to oxygen depletion than fish, control measures should be applied earlier.

Cultured under good pond conditions and with an ample supply of rich food, young prawns of about 4 to 5 cm in length and 1 to 2 g in weight are able to grow to about 20 cm, weighing about 100 g, in 5 to 6 mo. Two crops of prawns can therefore be cultured in 1 yr when the ponds are well managed. Harvesting can be done either by draining the pond or by seining.

6.2 Culturing in padi-fields

Irrigated padi-fields that are able to retain a depth of water of not less than 12 cm throughout the padi-growing period (about 4 mo) are suitable for stocking with young prawns.

The bunds of the padi-field should be slightly raised and its water inlets and outlets properly screened to prevent escape of prawns and entry of predatory fish. The water-inlet-screen should be strong and high, about 1 ft higher than the water surface, to prevent prawns from climbing over and escaping.

One or two small sump-pits, each of about 1 m x 2 m and 50 cm deep, should be constructed at the lower end of the field, close to the water outlets, for reception of prawns when the field is drained.

Young prawns should be introduced into the padi-field when the transplanted padi seedlings are fairly well rooted. A stocking rate of 1 young prawn to every 10 m^2 is recommended for padi-fields of average fertility. No supplementary feeding is necessary.

For stocking in padi-fields, prawns of over 3 mo old, about 6 to 7 cm in length, are preferred. Such prawns will be able to grow almost to maturity by the end of the padi growing period.

Prawns should be harvested at the time when the field is drained prior to padi harvesting. As the field is drained slowly, most of the prawns will retreat gradually to the lower end of the field and finally into the sump-pits, which still retain a certain amount of water when the field is completely drained. A short-handled hand-net is a convenient tool for fishing out the prawns from the sump-pits.

Prawns can be cultured in padi-fields together with fish such as Trichogaster pectoralis, T. trichopterus and Puntius gonionotus, which feed on plants or plankton.

Apart from the kinds and quantities of fertilizers normally used for padi cultivation, additional application of fertilizer is usually not required, and no supplemental feed is needed.

Since prawns are very sensitive to chemical insecticides, stocking of prawns is not recommended for padi-fields where such insecticides are normally applied.

7 REFERENCES

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CONSIDERACIONES SOBRE LOS INDICES METABOLICOS Y LA SUPERVIVENCIA DEL CAMARON BLANCO, *Penaeus schmitti* BURKENROAD, DE LA PLATAFORMA CUBANA

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Extracto

Se presentan las consideraciones de los trabajos realizados sobre los índices metabólicos y la supervivencia del camarón blanco *Penaeus schmitti* Burkenroad.

Se explican los métodos seguidos y los resultados del consumo de oxígeno, según la talla de los ejemplares y la relación existente entre ellos; el balance energía-oxígeno; la ventilación y la supervivencia en diferentes salinidades y ambientes. Se hizo un análisis del método de almacenaje y cómo realizarlo. Los trabajos se efectuaron en enero-febrero de 1967 y son sólo preliminares, proponiéndonos continuar los mismos para su ampliación.

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ASPECTS OF THE METABOLIC INDICES AND SURVIVAL OF THE WHITE SHRIMP, Penaeus schmitti BURKENROAD, ON THE CONTINENTAL SHELF OFF CUBA

Abstract

Research on metabolic indices and survival of the white shrimp, Penaeus schmitti Burkenroad, is reviewed. Methods followed are described and findings given in respect of oxygen consumption as related to the size (length) of the specimens in the form of the ratio: oxygen consumption to size; the energy/oxygen balance; tank ventilation; and survival at different salinities and in different environments. The method of live storage is analyzed and suggestions for proper storage are given. The research described was conducted in January to February 1967. It was only preliminary in character and it is proposed to continue the work.

CONSIDERATIONS SUR LES INDICES METABOLIQUES ET LA SURVIE DE LA CREVETTE Penaeus schmitti BURKENROAD DU PLATEAU CONTINENTAL CUBAIN

Résumé

Les auteurs présentent les résultats de travaux portant sur les indices métaboliques et la survie de la crevette Penaeus schmitti Burkenroad. Ils décrivent les méthodes appliquées et donnent des renseignements sur la consommation d'oxygène, selon la taille des échantillons, les rapports entre ces derniers, le bilan énergie-oxygène, la répartition et le taux de survie des crevettes en fonction du degré de salinité et des facteurs écologiques. Ils étudient une méthode d'emmagasinage et proposent des solutions pratiques en la matière. Leurs travaux, réalisés en janvier-février 1967, sont essentiellement préliminaires, et il est envisagé de les poursuivre en les amplifiant.

1 INTRODUCCION

Nos proponemos realizar el estudio de la fisiología del camarón blanco debido a la importancia que presenta en nuestras pesquerías, con el fin de estudiar las características fisio-ecológicas, posibilidades de aclimatación, cultivo artificial, localización de nuevas áreas de pesca, transporte y almacenamiento; para obtener ésto tuvimos que estudiar la fisiología respiratoria, balance energético, supervivencia y almacenamiento.

Los índices metabólicos que exponemos sirven de pauta para localizar nuevas zonas de pesca correlacionando los valores óptimos con los encontrados en el medio acuático; la aclimatación es posible, pues, buscando áreas de características idóneas donde no exista la especie, se podrían repoblar llevando los ejemplares de una zona a otra utilizando medios de transporte adecuados. Para iniciar el cultivo artificial del camarón se hace necesario el conocimiento de la fisiología de la especie, la cual nos ayuda a comenzar sin dar rodeos para encontrar la forma ideal.

El almacenamiento del camarón es algo que nos preocupa a todos pues para la construcción de centros de acopio, para su cultivo, es necesario conocer la forma con la que se mantienen mejor y de una manera óptima los ejemplares sin que vaya en su detrimento.

No pretendemos con esta contribución resolver de un modo definitivo aquellos problemas fisio-ecológicos que necesitamos para solucionar los de la industria camaronera en Cuba; esto requeriría numerosos experimentos en un período mayor de tiempo; pero sobre la base planteada aquí, debemos proseguir las investigaciones hasta llevar a cabo un trabajo completo.

Consideramos este aporte al conocimiento de la biología del camarón como una pauta a seguir. Las conclusiones planteadas por nosotros no deben tomarse como definitivas, sino como un medio por el cual proseguiremos hasta adentrarnos en las conclusiones generales sobre los camarones cubanos. Los experimentos se realizaron en un período comprendido entre los meses de enero-febrero de 1967.

Hacemos presente nuestro agradecimiento a todos aquellos que nos ofrecieron su ayuda para el desarrollo de nuestra misión; a Miroslav Nikolić, experto de la FAO y a Ramón García Subías que revisó el trabajo. Los datos del metabolismo respiratorio fueron elaborados por María Elena Ramiro G.

Las fotografías y diapositivas fueron efectuadas por el fotógrafo del Centro de Investigaciones Pesqueras, Sixto R. González Leyva. Los gráficos fueron realizados por la Dra. Emma Móser.

2 MATERIALES Y METODOS

2.1 Determinación del oxígeno

Todas las determinaciones del oxígeno disuelto en el agua fueron realizadas por el método standard de Winkler. Yoder y Dresher (1934) estudiaron los efectos de los reactivos químicos que se usan en este método, llegando a la conclusión de que era utilizable, ya que el resultado obtenido es bastante exacto.

El método requiere que las muestras a examinar sean tratadas con una solución alcalina de sal manganosa, que forma un precipitado de hidróxido manganaso, que cuando es acidulado en exceso en presencia de yoduro, libera yodo cuantitativamente en forma de ión-triyoduro lo cual se realiza en cantidades equivalentes a la de oxígeno disuelto presente en la muestra de agua; el ión tri-yoduro viene titulado con una solución valorada de tiosulfato de sodio, lo cual nos ofrece los ml O_2l/l que se presentan en el agua sometida a estudio.

Se determinó el oxígeno del agua removida por las branquias del animal así como el que había en el agua antes de ser removida; con la diferencia se obtiene el consumo.

El tiempo que debe durar el experimento está determinado por el que el ejemplar utiliza consumiendo solamente una tercera parte del oxígeno disuelto inicialmente en el agua, ya que de otro modo se alteraría sensiblemente su metabolismo.

2.2 Método de medir el consumo de oxígeno

El aparato utilizado en la respirometría (Fig. 1) consiste en un depósito de vidrio de una capacidad de 8 litros, el cual presenta dos orificios, uno superior y otro inferior; por el inferior entra el agua y por el superior sale. La entrada es regulada por una llave que auxiliada por una probeta graduada y un cronómetro, sirve para controlar el experimento a una fluidez premeditada en el período de una hora, tiempo que dura cada experimento.

Se utilizaron cada vez cuatro respirómetros, los cuales se encontraban comunicados con un tanque de 5.000 galones donde se almacena el agua de mar que surte a las peceras del Centro de Investigaciones Pesqueras. Al presentar un volumen tan grande se elimina el peligro de que varíe la fluidez debido al descenso de la presión ejercida por el volumen del agua.

Los respirómetros usados son de circuito abierto por lo que la fluidez se mantenía continuamente; el volumen de agua disponible para cada experimento varió entre 6 y 60 l/h con el fin de estudiar la secuencia respiratoria.

Los experimentos se realizaron durante los meses de enero-febrero de 1967 a una temperatura promedio de 25°C y una salinidad de 36°/oo, no encontrándose otros valores; estos datos uniformes nos indican que se pueden considerar como relación exacta con los datos planteados aquí.

2.3 Determinación de salinidades sub y supranormales

Para esta serie de experiencias fueron utilizados unos recipientes de cristal con una capacidad aproximada de 30 l de agua, la cual se mantenía constantemente oxigenada por medio de la inyección de aire.

Las salinidades sub-normales fueron obtenidas mezclando agua dulce con agua de mar y controladas con la ayuda de un densímetro, cuya lectura era rectificada de acuerdo con la temperatura en la tabla de correcciones del instrumento. Las salinidades supranormales fueron obtenidas añadiéndole al agua de mar distintas proporciones de sal en grano, rectificándose las mismas por el método de Mohr-Knudsen. En ambos casos los ejemplares fueron pesados, medidos y se determinó en cada caso su sexo.

2.4 Método de almacenamiento

Para ello fue utilizado un tanque de fibrocemento de 200 l. El contenido de agua de mar del tanque fue mantenido en 190 l. Las muestras de oxígeno eran tomadas periódicamente y la temperatura fue tenida en cuenta en todos los casos.

Se tuvo siempre la precaución de separar inmediatamente del tanque al ejemplar muerto y tomar en ese mismo instante una muestra de oxígeno. Los ejemplares muertos fueron pesados en una balanza de precisión; se determinó su sexo y el largo total.

2.5 Camarones

Los camarones utilizados para este trabajo pertenecen a la especie Penaeus schmitti Burkenroad. Los camarones fueron capturados en Tunas de Zaza y Cienfuegos, en la zona sudoriental de la plataforma cubana y traidos al laboratorio en un tanque vivero, el cual se encontraba lleno de agua oxigenando ésta con dos difusores de aire que la

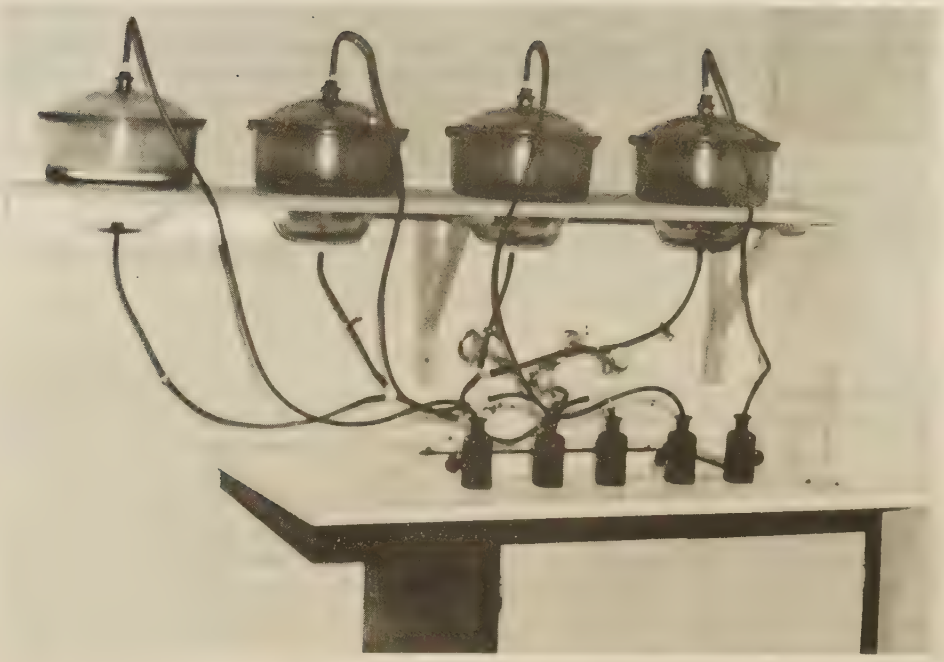

Fig. 1 Respirómetro de circuito abierto, utilizado para determinar el consumo de oxígeno. Capacidad: 8 litros

mantenían constantemente en buenas condiciones para la vida de los camarones. Antes de comenzar los experimentos aclimatamos los ejemplares durante diez días, evitando así los efectos que se producen en el metabolismo al alterarse toda la integración del organismo.

Todos los datos de respiración se obtuvieron al estudiar diferentes ejemplares, cuyos pesos en gramos se observan en el Cuadro I; los utilizados para la supervivencia y almacenamiento se ven en el Cuadro VII.

CUADRO I

Datos sobre sexo, peso (g) y talla (mm) de los camarones utilizados con la fluidez óptima para cada clase

CAMARON	SEXO	PESO (g)	LARGO (Lt / mm)	FLUIDEZ OPTIMA 1/h
I	♀	11,2	80,0	24
II	♂	12,5	85,0	36
III	♂	14,0	90,0	36
IV	♂	15,0	94,5	36
V	♀	19,0	102,0	40
VI	♀	22,5	105,5	40
VII	♀	53,0	135,0	60

3 METABOLISMO

Entendemos por metabolismo todos aquellos cambios de materia y energía que se producen en un organismo.

Según la primera ley de la termodinámica, la energía tomada por el organismo es igual a la que da, más la que retiene; conociendo un índice de esta ecuación obtendremos una estimación cuantitativa del metabolismo.

El método utilizado por nosotros para estimar los índices metabólicos es el basado en la suposición - válida para todos los organismos que se encuentran en condiciones normales- de que todos los procesos que originen energía llevan en ellos consumo de oxígeno y expulsión de anhídrido carbónico.

El consumo de oxígeno se puede expresar según la ecuación:

$$Q_t = c\ W^n$$

donde:

c = expresión del ritmo metabólico, característica de la especie, sin relación alguna con el peso.

n = índice de utilización de oxígeno o coeficiente de regresión; cuando su valor es cercano a la unidad expresa que el metabolismo es proporcional al peso del ejemplar; si su valor es menor quiere decir que es proporcional a la superficie corporal. (Buesa, MS).

Generalmente n es menor que 1 y el valor medio está próximo a 0,73.

El consumo de oxígeno estimamos que es alterado por ciertos factores intrínsecos y ecológicos, tales como: actividad, estado de nutrición, sexo, hora del día, estación del año, edad, estado de desarrollo, proceso de muda, temperatura, presión osmótica, oxígeno y anhídrido carbónico disuelto en el agua.

El factor principal para relacionar el consumo de oxígeno es el área del cuerpo, pero como resulta difícil, se utiliza el peso de los ejemplares.

Es de importancia el estudio de las actividades metabólicas, pues podrían actuar como factores limitantes en la supervivencia y distribución. En el caso del camarón blanco, P. schmitti, representamos el índice del metabolismo como su equivalente de microlitros de oxígeno por gramo húmedo en una hora o bien como los mililitros de oxígeno por kilogramo húmedo a la hora.

En general la cantidad de oxígeno que consume un animal es el reflejo de los procesos metabólicos que ocurren en él, tales como su crecimiento (cíclico), la digestión, excreción, circulación y osmorregulación en diferentes condiciones que pueda encontrarse.

El camarón, como generalmente todo animal marino, respira por medio de branquias, las cuales son sacos alargados de epitelio simple plano, por donde circula la sangre en sentido opuesto a la del agua, para permitir los intercambios gaseosos medio-ejemplar efectuándose la respiración.

El intercambio respiratorio en el camarón, se realiza al pasar el agua de mar por las branquias, las cuales se encuentran en las cámaras branquiales entre las branquiosteguitos y la pared del cuerpo. En la porción delantera de cada cámara se inicia un canal, en el cual el escafognatito de la segunda maxila se mueve hacia atrás y hacia adelante, provocando la salida del agua por la porción trasera de dicho canal.

El agua trae el oxígeno disuelto (alrededor de 5,79 ml O_2/l); se continúa el intercambio al expulsar paralelamente el anhídrido carbónico de desecho al exterior; pero para poder efectuar este proceso, el animal tiene que consumir energía y acumular reservas potenciales que utiliza para su desarrollo y comportamiento en el medio.

3.1 Respiración

Llamamos respiración al intercambio de gases y la velocidad del metabolismo, en función del peso del cuerpo o de su volumen. Al aumentar el metabolismo de un ejemplar dado, nos indica que es consecuencia de un mayor suministro de alimentos.

La sangre de los crustáceos presenta un pigmento, la hemocianina, encargado de efectuar el intercambio respiratorio, que puede combinarse reversiblemente con el oxígeno; es una cuproproteína que se disuelve en la hemolinfa del camarón y no contiene porfirinas. Por oxigenación se une una molécula de oxígeno por cada dos iones de cobre, los que existen en estado cuproso, (Haurowitz, 1966).

Como indicamos anteriormente la respiración se produce mediante el intercambio de gases, producido al pasar una corriente de agua por las branquias; la capacidad de regular las corrientes respiratorias son proporcionales a la necesidad respiratoria.

Como el camarón es un animal poiquilotermo, estimamos (aunque no se realizaron experimentos a diferentes temperaturas) que la variación en °C del agua de mar influye de un modo directo sobre su metabolismo, acelerándolo o retardándolo según aumente o disminuya, respectivamente.

3.1.1 Consumo de oxígeno según la talla de los ejemplares

El consumo de oxígeno según la talla nos indica que ejemplares menores de *P. schmitti* consumen menos oxígeno por cada litro de agua de mar. A una fluidez mínima de 6 l/h , el animal posee un consumo alto pero al llegar a 24 l/h , después de un descenso bastante brusco, se mantiene casi estable descendiendo poco, pero se observa que a una fluidez de 60 l/h el consumo se hace mínimo.

El porcentaje de oxígeno consumido según la fluidez (Fig. 2) por clases de peso, nos indica los valores máximos y mínimos de consumo para cada animal, entre el 3 y el 10. Se mantiene todo el consumo para una cantidad disponible de agua que oscila entre 6 y 60 l/h. El porcentaje de consumo aumenta con la longitud de un ejemplar, que está relacionada con su peso; los mayores de 95 mm presentan un aumento considerable del consumo de oxígeno, siendo estos datos observados para la ventilación óptima de cada camarón.

Consumos de oxígeno por hora, máximos, mínimos y promedios según su porcentaje, figuran en el Cuadro II, que indica que con un volumen de ventilación óptimo y en un período de tiempo de una hora, se incrementa el porcentaje de consumo de oxígeno expresado en $ml/O_2/l/h$ al aumentar el peso del ejemplar.

CUADRO II

Consumo de oxígeno ($mlO_2/l/h$) máximo, mínimo y promedio según su porcentaje de consumo por clases en *P. schmitti*

CAMARON	MAXIMO	%	MINIMO	%	PROMEDIO	%
I	0,250	4,94	0,014	0,19	0,114	1,53
II	0,362	6,74	0,035	0,07	0,057	0,97
III	0,456	8,98	0,045	0,67	0,114	1,94
IV	0,504	10,11	0,056	1,12	0,146	2,88
V	0,560	11,23	0,060	1,23	0,156	3,14
VI	0,817	16,40	0,176	3,48	0,336	6,65
VII	0,946	18,65	0,103	1,80	0,275	4,36

En el camarón blanco el consumo total de oxígeno representado en $ml/O_2/l/h$ para los ejemplares menores es inferior al de los ejemplares mayores. En la Fig. 3, las curvas del punto más alto, representan el consumo máximo por ejemplar.

El consumo de oxígeno a causa del crecimiento se redobla a veces, siendo superior en los ejemplares que se hallan en el ciclo de preparación para la próxima ecdysis. El de 135 mm presenta un metabolismo no proporcional a su talla debido a que sus períodos ecdysicos se hacen más lejanos, para lo cual no es necesario un metabolismo tan alto como los menores que sí lo necesitan para su integración cíclica.

Debemos señalar que es probable que en ciertos habitat se encuentren, debido al fondo fangoso y al calor, zonas de escaso oxígeno. Los fondos orgánicos absorben éste y surge la necesidad de estudiar la capacidad de supervivencia en aguas con bajo contenido de oxígeno.

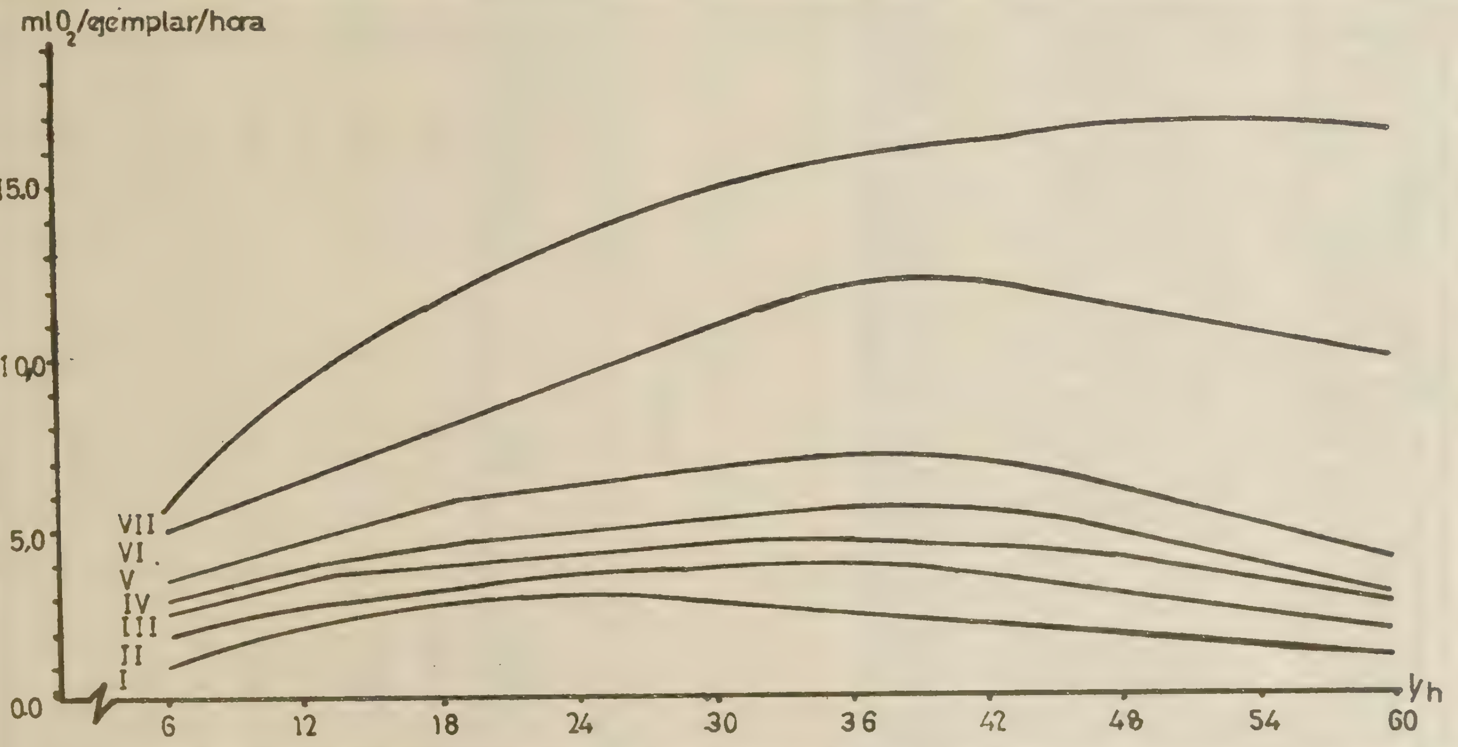

Fig. 2 Consumo total de oxígeno según la fluidez del agua.

3.1.2 Indice metabólico y talla

Los ritmos metabólicos menores están descritos para aquellas especies bentónicas grandes y relativamente sedentarias, como Homarus gammarus 65 µl-O_2/g/h a 15°C (Jolyet y Regnard, 1877), Panulirus argus, entre 4-5 años, 69-73,5 µl-O_2/g/h a 29,2°C, (Buesa, MS). El camarón P. schmitti es una especie pequeña y de hábitos no sedentarios, por lo que el índice metabólico expressado en microlitros de oxígeno por gramo húmedo a la hora tendrá un valor relativamente alto semejante a Ligia oceánica 175-400 µl-O_2/g/h a 25°C (Ellenby, 1951).

En cada curva del índice metabólico hay un punto máximo el cual representa el consumo máximo por peso húmedo a la hora, entre los 32 y los 42 l ; éstos corresponden a la ventilación óptima de 26 l /h para el consumo de cada animal; en cada curva observamos una pendiente ascendente y otra descendente que nos indica que a volumen de ventilación menor que la óptima el índice metabólico es menor y a mayor de la óptima también será menor en relación con la cantidad total de oxígeno; quiere decir ésto que los mecanismos respiratorios están influenciados por la ventilación disponible del agua, haciendo ésto variar sensiblemente el consumo.

Si analizamos el índice metabólico según la talla notaremos que a ejemplares mayores corresponde un mayor índice. Ello es posible porque los ejemplares mayores presentan un metabolismo más alto, lo cual requiere más consumo de oxígeno. Asimismo presentan un ciclo de reproducción más completo, representando ésto un incremento en el metabolismo (Cuadro III).

CUADRO III

Resultado de los experimentos de respiración en P. schmitti

CAMARON	FLUIDEZ	PESO	CONSUMO	
			ml O_2/ej /h	µl O_2/g/h/
I	100-1000	11,2	2,74	244,6
II	100-1000	12,5	3,70	296,0
III	100-1000	14,5	4,10	292,8
IV	100-1000	15,0	5,26	350,6
V	100-1000	19,0	6,55	344,7
VI	100-1000	22,5	12,04	535,1
VII	100-1000	53,0	16,50	311,3

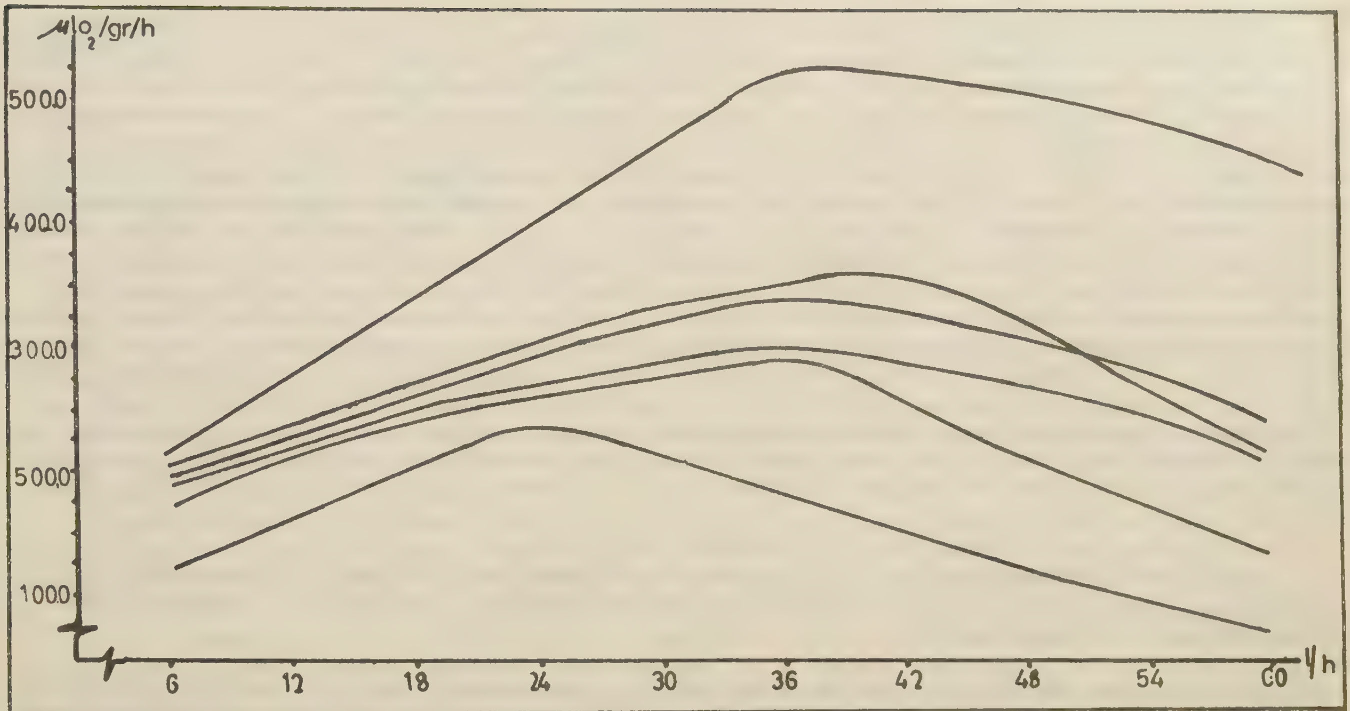

Fig. 3 Relación entre el índice metabólico y el peso de los ejemplares: Temperatura, promedio 25°C; Salinidad, promedio 36°/oo.

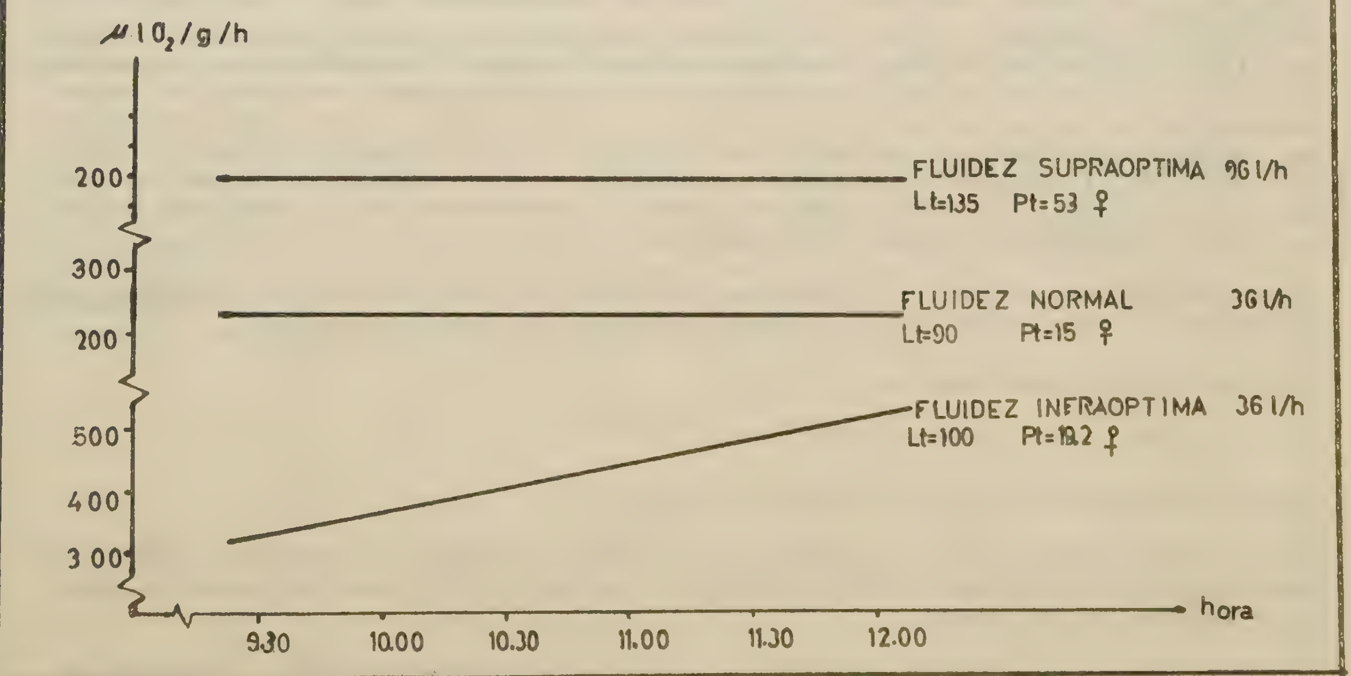

Fig. 4 Utilización del oxígeno a fluidez normal y anormal según el tiempo.

A fin de determinar si estos datos se corroboran, se realizaron varias experiencias, para las cuales utilizamos ejemplares de 15, 19 y 53 g de peso (Fig. 4). Para un ejemplar de 15 g según datos que encontramos, el volumen de ventilación óptimo es de 36 l/h; se investigó a diferente fluidez y el consumo durante un período de 3 horas consecutivas se mantuvo constante. Un ejemplar de 19,2 g cuya fluidez óptima oscila entre 40 l/h se estudió a 36 l/h y el índice de utilización fue aumentando progresivamente con lo que se demostró que a una fluidez menor de la óptima, el animal hace mayor esfuerzo metabólico y aumenta el consumo de oxígeno. Un ejemplar de 53 g cuya ventilación óptima oscila alrededor de los 54 l/h se estudió a 96 l/h ; el índice de utilización de oxígeno se mantuvo constante, lo que indica que a una ventilación mejor que la óptima, el animal mantiene a nivel constante su consumo óptimo. En los tres casos, el primer valor encontrado coincide con el índice de utilización para ese peso a dicha fluidez; en el caso de la óptima, el consumo se mantiene constante, pero en la menor el consumo aumenta. Podemos generalizar que el mejor índice de utilización de oxígeno lo encontramos según la fluidez óptima de cada ejemplar a un peso determinado; para un ritmo de ventilación menor el consumo aumenta y para uno mayor se mantiene constante, pero disminuye porque a mayor cantidad de agua el animal utiliza sólo la necesaria para su mecanismo respiratorio.

Los datos presentados aquí los podemos considerar como bastante aproximados al metabolismo principal, pues los ejemplares se mantuvieron quietos en el respirómetro mientras duró el experimento.

La velocidad de utilización del oxígeno que corresponde con el nivel del metabolismo general del balance de energía y materia es una característica fundamental para cada animal.

3.1.3 Relación entre el peso y el consumo de oxígeno

El estudio de la tendencia a las variaciones existentes entre el largo y el peso de P. schmitti se lleva a cabo porque nos permite, conociendo el peso de un ejemplar o su peso total, determinar por medio de cálculos teóricos cuál será el consumo de oxígeno de ellos, dato necesario para el almacenamiento, traslado y cultivo de los camarones. El análisis de los datos de la relación peso-consumo de oxígeno, nos facilitó la determinación de las variaciones que ocurren en el metabolismo, relacionadas con el peso, pudiéndose estudiar el incremento en $\mu l\text{-}O_2/g/h$ de los ejemplares según su peso. El estudio de la correlación existente entre el peso y el consumo de oxígeno nos da una recta positiva; la correlación es directa, indicándonos que a ejemplares de mayor peso el consumo de oxígeno será superior.

Se utilizó el método de los mínimos cuadrados a fin de obtener una ecuación capaz de ofrecer el consumo teórico de oxígeno conociendo el peso del ejemplar.

La ecuación resultante es:

$$Q_{25^{o}} = 16{,}75 \qquad W^{0.992156} \qquad [1]$$

donde el logaritmo de 16,75 es igual a 1.224140

El valor de n generalmente está entre 0,67 y 1,00 (Wolvekamp y Waterman, 1960). En estos casos el metabolismo es proporcional al volumen total, peso del animal o área de la superficie del cuerpo.

Para P. schmitti los valores de c y n son los siguientes a 25°C y salinidad de $36^{0}/00$.

Constante a 25° y $36^{0}/00$

c 16,75

n 0,992156

Estos datos nos permiten señalar que:

a) el consumo total de oxígeno está en función directa con el peso: a mayor peso éste se incrementa;

b) la utilización del oxígeno o índice metabólico es inversamente proporcional al peso expresado en gramos húmedo;

c) los ejemplares mayores poseen un metabolismo más activo debido a la complejidad de sus funciones.

Con la ecuación [1] construimos el Cuadro IV, en el que se aprecia que son ciertos los datos obtenidos, pues los consumos observados y los teóricos son semejantes. Los datos fueron ajustados y comprobados a los fines de la ecuación.

Los valores 16,75 y 0,992156 correspondientes a c y n respectivamente, son índices de la especie, los cuales se mantienen constantes independientemente del consumo y el peso de los ejemplares tratados, los cuales corresponden a índices metabólicos de *P. schmitti*.

Mediante los valores expresados anteriormente podemos calcular acertadamente el consumo de oxígeno de ejemplares conociendo su peso. Según nuestros experimentos llevados a cabo en el laboratorio $\bar{Q}$ 25° = 263,1 μl- O_2/g/h ; nos indica que la utilización del oxígeno en *P. schmitti* es superior a ciertos organismos bentónicos mayores que él, tales como *Panulirus elephas* a 15°C, 44 μl- O_2/g/h (Jolyet y Regnard, 1877).

Los datos calculados teóricamente ofrecen un $\bar{Q}$ 25° = 263,3 μl- O_2/g/h , lo que indica que los valores son ciertos y pueden ser tomados como índice para esta especie.

CUADRO IV

Utilización del oxígeno, observada y teórica, según los pesos de los camarones

CAMARON	PESO	OBSERVADO	TEORICO
I	11,2	159	184
II	12,5	217	209
III	14,5	244	230
IV	15,0	266	246
V	19,0	270	310
VI	22,5	400	380
Promedio	16,1	263,1	263,3

E/32

4 BALANCE - ENERGIA - OXIGENO

Una digestión intensa produce un incremento del consumo de oxígeno, lo cual se revela mediante experimentos.

En 100 mg de carbohidratos por litro de agua de mar, se ve que 1 mg proporciona por cada litro de agua filtrada por las branquias el alimento requerido por el ejemplar consumiendo más oxígeno cuando la digestión de los carbohidratos es más intensa (Collier, Ray y Magnitzky, 1950).

Para expresar el balance de energía nosotros usamos los valores utilizados por Collier (1959):

1 ml de O_2 = 1,43 mg de peso

1 mg de O_2 = 1,17 mg de carbohidratos

1 mg de carbohidratos = 4,1 calorías

1 caloría = 4.185 joules

1 ml de O_2 = 4,83 calorías

4.1 Gasto de energía durante la respiración

El gasto de energía utilizada en la respiración se expresa en calorías gramo a la hora.

Como sea que los ejemplares más pequeños consumen menor cantidad de oxígeno, el volumen de utilización en calorías es, lógicamente, menor para los pequeños y mayor para los grandes. La curva obtenida del peso de los ejemplares frente a las cal/g/h, presenta valores de 600 y 1900 cal/g/h para los ejemplares estudiados (Fig. 5) que van ascendiendo a medida que el peso se hace mayor; invariablemente esto ocurre a expensas del índice metabólico de la especie tratada.

Esta utilización de calorías-gramo hace que para que un animal lleve a cabo su función metabólica sea consumida cierta cantidad de mg. de carbohidratos;como esperábamos, el metabolismo de los ejemplares mayores es más alto consumiendo, por tanto, mayor cantidad de carbohidratos en relación directa con la talla de los ejemplares. El consumo de carbohidratos oscila entre 175 y 450 mg/h en los estudiados. En el Cuadro V observamos el consumo de energía al día por respiración, expresado en calorías según la talla de los ejemplares que está expresada en ml O_2/camarón/día. Los ejemplares mayores consumen más energía al día representada por el consumo ejemplar/día; su valor promedio oscila entre 842,72/cal/g/día.

4.2 Trabajo y eficiencia del bombeo

El trabajo realizado por los camarones para obtener eficientemente el consumo de oxígeno lo expresamos en joules y es el efectuado por las branquias para obtener el volumen óptimo de $\mu l-O_2$/g/húmedo/h en el intercambio respiratorio.

Los ejemplares más grandes realizan un trabajo más eficiente pues al tener su metabolismo más alto que los de menor talla, necesitan realizar un trabajo mayor a fin de obtener el oxígeno óptimo que se encuentra disuelto en el mar.

El trabajo realizado por los camarones que utilizamos durante los experimentos de laboratorio fue de 800 a 2.000 j/h , que está distribuido de la siguiente manera: para los ejemplares más pequeños, menor trabajo y mayor para los más grandes.

CUADRO V

Consumo de energía por respiración a la hora y día según el peso del camarón

CAMARON	ml O_2/ej /h	ml O_2/ej /día	Consumo de energía por respiración expresado en calorías
I	2,74	65,76	317,62
II	3,70	88,80	428,90
III	4,10	98,40	475,27
IV	5,26	126,24	609,74
V	6,55	157,20	759,28
VI	12,04	288,96	1395,68
VII	16,50	396,00	1912,68

CUADRO VI

Resumen del balance energético según peso

PESO	µl O_2/g/h	Calorías/hora	mg/CARBOHIDRATOS	JOULES
11,2	158,9	767,5	186,5	780,5
12,5	217,8	1051,9	255,6	1069,7
14,0	244,1	1179,0	286,5	1199,0
15,0	266,7	1288,2	313,0	1309,9
20,0	269,1	1299,8	315,9	1321,4
22,5	400,6	1934,9	470,2	1967,8

En el Cuadro VI se presenta un resumen del balance energético de P. schmitti según peso, en que se esboza el metabolismo de estos crustáceos.

5 VENTILACION

El intercambio entre el medio y la superficie respiratoria de las branquias se efectúa como una difusión. Para que se produzca este intercambio, el oxígeno disuelto en el agua debe encontrarse a corta distancia del animal para una adecuada respiración teniendo el coeficiente de difusión un valor cercano a 10^{-6} (Wolvekamp y Waterman, 1960). Generalmente la difusión es ayudada por la convexión existente entre el medio y la superficie respiratoria.

5.1 Volumen de ventilación

Este dato se presenta como un parámetro importante y es la cantidad de agua transportada en una hora por un ejemplar desde el inicio de la cavidad branquial hasta el

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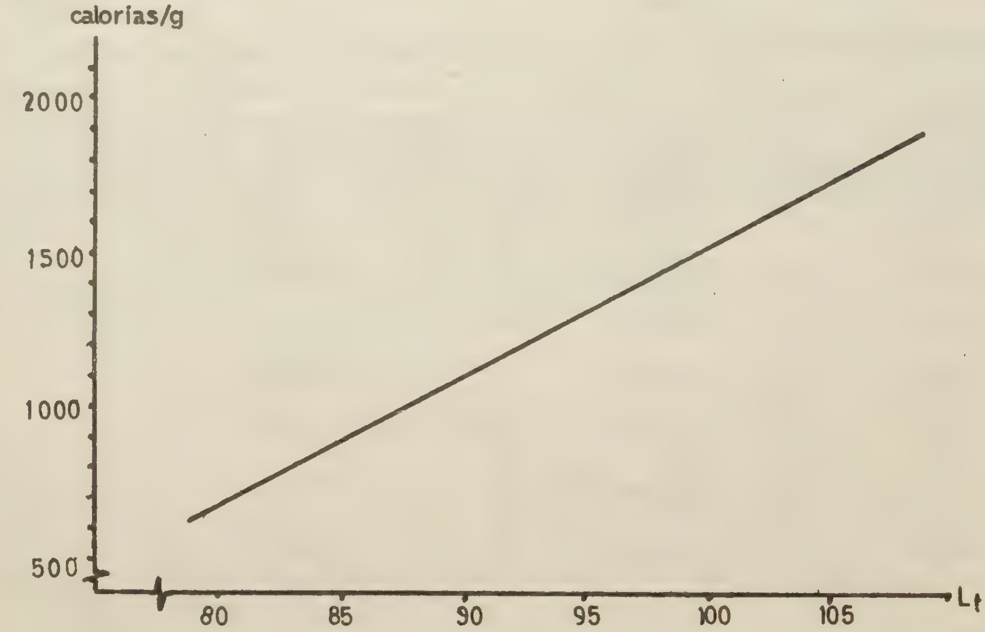

Fig. 5 Utilización del oxígeno expresado en pequeñas calorías.

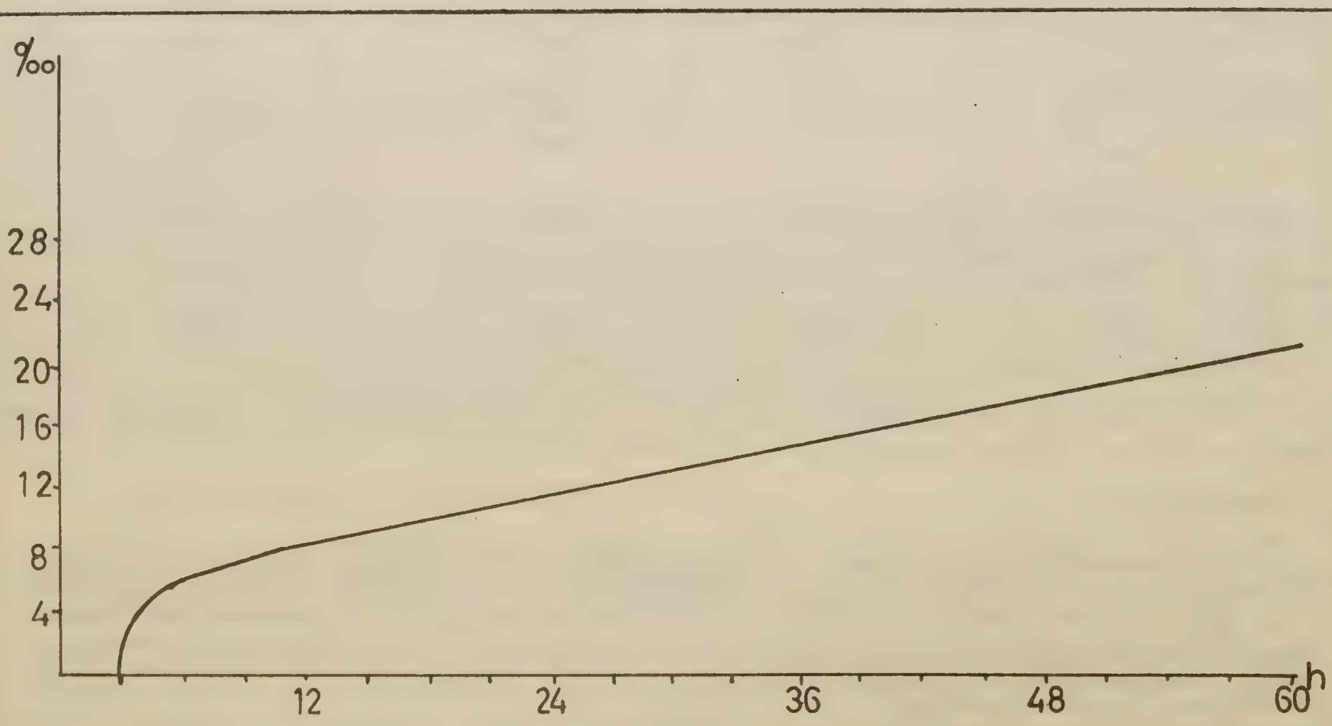

Fig. 6 Supervivencias en horas contra salinidad subnormal para P. schmitti

final de la misma y se mide por el transporte de colorantes diluidos en el agua que circunda el animal.

Los ejemplares mayores de vida más sedentaria presentan un volumen de ventilación menor que aquellos de vida más activa; como sabemos, en Homarus gammarus es de 9,6 - 9,9 l/h. a 15°C, para un ejemplar de 322 g , lo cual nos indica que representando en consumo/peso el resultado es igual a 29,8-30,7 ml/g/h (Thomas, 1954). La ventilación está muy relacionada con la velocidad de la corriente de agua formada por los pleópodos del ejemplar tratado; ella depende de la condición en que se encuentre el ejemplar. No tendremos el mismo resultado para un camarón que bate sus apéndices natatorios, que para el que no presente ningún tipo de movimiento o que los bata lentamente. Para P. schmitti con un promedio de 16,1 g de peso, describimos un volumen de ventilación de 9 l/h a 20°C lo que es igual a 55,9 ml/g/h.

6 SUPERVIVENCIA

6.1 Supervivencia en aguas de salinidades infra-normales

Nuestro propósito al llevar a cabo este tipo de experimentos se basa en indagar sobre el posible comportamiento de esta especie en aquellas épocas del año en las que frecuentes precipitaciones pueden alterar en una u otra forma, la salinidad óptima de P. schmitti, determinando una migración en aquellas zonas que así lo permitan, o su resistencia a esta adversidad en aquellas, que por su naturaleza, impongan la estancia de la especie.

Los camarones utilizados en estos experimentos provinieron de zonas cuya salinidad promedio es de 35 $^{0}/00$ (Nikolić y García, 1968).

De acuerdo con los resultados obtenidos en los distintos experimentos la supervivencia en horas de P. schmitti queda representada gráficamente por una curva de las características en la Fig. 6, en que se verifica un brusco ascenso en la supervivencia de la especie en el intervalo de salinidad comprendido entre 0 a 6 $^{0}/00$ para luego hacerse menos pendiente, correspondiendo siempre un aumento en la supervivencia a un incremento de la salinidad infra -normal. Esto en general se cumple para valores de salinidad de hasta 25 $^{0}/00$ donde hemos podido observar que los camarones mantenidos en estas condiciones presentan la adaptabilidad necesaria para poder sobrevivir a dichas experiencias. Todos los ejemplares de P. schmitti que fueron sometidos a experimentos, sobrevivieron en un intervalo de salinidad entre 25 $^{0}/00$ y 30 $^{0}/00$.

6.2 Supervivencia en aguas de salinidades supra-normales

Con propósito semejante al de la supervivencia en salinidades infra-normales, hemos llevado a cabo este tipo de experimento cuyo resultado aparece en el Cuadro VII. Un aumento de la salinidad supra-normal, corresponde a una disminución en la supervivencia del ejemplar.

6.3 Supervivencia de P. schmitti en diferentes ambientes

En vista de un posible traslado de camarones vivos de un lugar a otro se han realizado una serie de experimentos con P. schmitti, consistentes en mantener algunos ejemplares en ambientes a distintas temperaturas y sin agua de mar.

Los resultados obtenidos figuran en el Cuadro VIII, correspondiendo las temperaturas menores al ambiente logrado manteniendo el ejemplar en refrigeración, las temperaturas intermedias con el ejemplar a la sombra y las más altas a su exposición a los rayos solares.

CUADRO VII

Datos de supervivencia en salinidades supra-normales de acuerdo con el peso del ejemplar

HORAS DE SUPERVIVENCIA	SALINIDAD SUPRA NORMAL (°/oo)	PESO DEL EJEMPLAR (g)
5:38	45	6
6:35	45	5,5
4:10	53	8,9
5:15	53	7,5
2:07	78	6,5
2:22	78	6

CUADRO VIII

Datos de supervivencia en relación con la temperatura (°C) del ambiente y el peso del ejemplar

TEMPERATURA DEL AMBIENTE (°C)	SUPERVIVENCIA (m)	PESO DEL EJEMPLAR (g)
14	31	13,8
23	21	17,6
23	20	16,5
23	16	5,7
32	6	10,2
32	5	8,1

7 ALMACENAMIENTO

Se llevaron a cabo experimentos de almacenamiento con ejemplares de un peso total de 82,5 g (5 camarones), para tener una base sobre la forma de almacenarlos correctamente, bien para acopiarlos o para mantenerlos en cultivo artificial del camarón blanco.

Los datos encontrados se presentan en el Cuadro IX. En la Fig. 7 se nota cómo a medida que transcurre el tiempo aumenta el consumo de oxígeno; la relación se mantiene constante hasta agotar todo el oxígeno llegando a morir todos los ejemplares poco a poco; si no son retirados los que han muerto, se descompone el agua disminuyendo su contenido de oxígeno; para hacer correctamente el experimento fueron extraidos los ejemplares muertos y en la Fig. 8 vemos que el porcentaje de comsumo de oxígeno a partir de las 66 horas, aumenta menos proporcionalmente según el tiempo; se debe ésto a la presencia de un menor número de ejemplares respirando.

La utilización del oxígeno se incrementa a medida que transcurre el tiempo, encontrándose valores entre 2-10 $\mu l\text{-}O_2/g/h$ aproximadamente (Cuadro IX).

Para facilitar el cálculo del consumo de oxígeno de un ejemplar o peso de diferentes camarones, durante el almacenamiento se utilizó el método de los mínimos cuadrados, relacionando el consumo de oxígeno con el tiempo en horas que durará el almacenamiento.

CUADRO IX
Consumo de oxígeno durante el almacenamiento para 190 litros

HORAS TRANSCURRIDAS	% CONSUMO	ml $O_2/l/h$	µl $O_2/g/h$
11	14,16	145,16	1,76
17	17,34	177,65	2,15
20	31,08	318,44	3,86
23	33,30	341,24	4,14
26	45,03	461,32	5,59
46	66,70	683,43	8,28
47	67,34	689,89	8,36
48	67,44	691,03	8,38
63	83,40	854,43	10,36
70	83,72	857,66	10,40
71	83,93	859,94	10,42
72	84,99	870,77	10,55
74	85,41	875,14	10,61

La ecuación resultante es la siguiente:

$$Q\ 24^{\circ} = 0{,}21\ T^{0{,}93}$$

donde: logaritmo de 0,21 es igual a -0,677444

$Q\ 24^{\circ}$ = consumo según el tiempo en horas a 24°C

T = tiempo transcurrido en horas para 190 litros de agua de mar.

Como el peso promedio del camarón blanco en diferentes zonas de pesca es de:

Tunas de Zaza = 13 gramos

Manzanillo = 7-26 gramos

tomamos para los cálculos de almacenamiento como peso promedio de P. schmitti 16,1 g que representa la media de todos los camarones utilizados en respirometría.

Consideramos que un consumo de oxígeno de un ejemplar no altera su vida, cuando no consume más del 35% del oxígeno total del volumen de agua donde se encuentre recluido.

PROPONEMOS:

a) Que para mantener ejemplares en estanques el volumen de agua que debe tener cada camarón al día es de 40 litros;

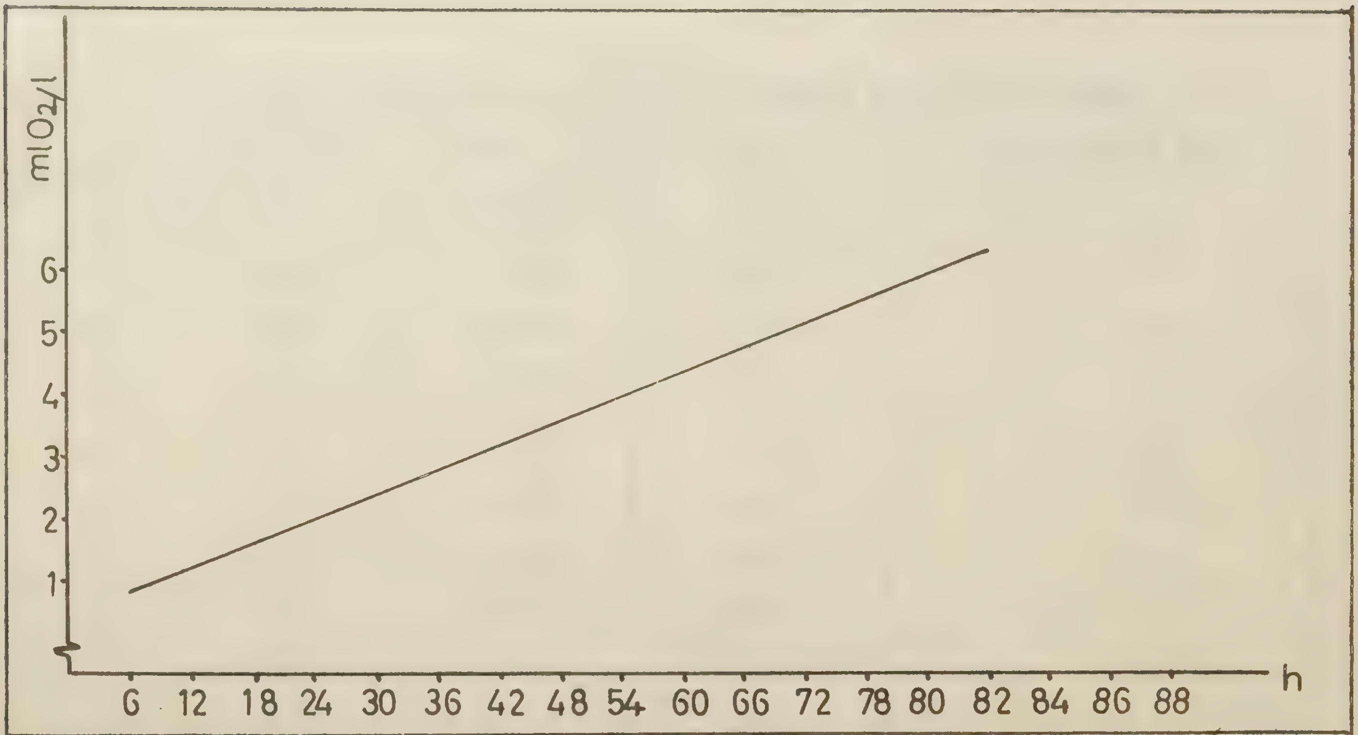

Fig. 7 Consumo de oxígeno durante el almacenamiento de 82,5 g (P. schmitti) en un tanque de 190 litros.

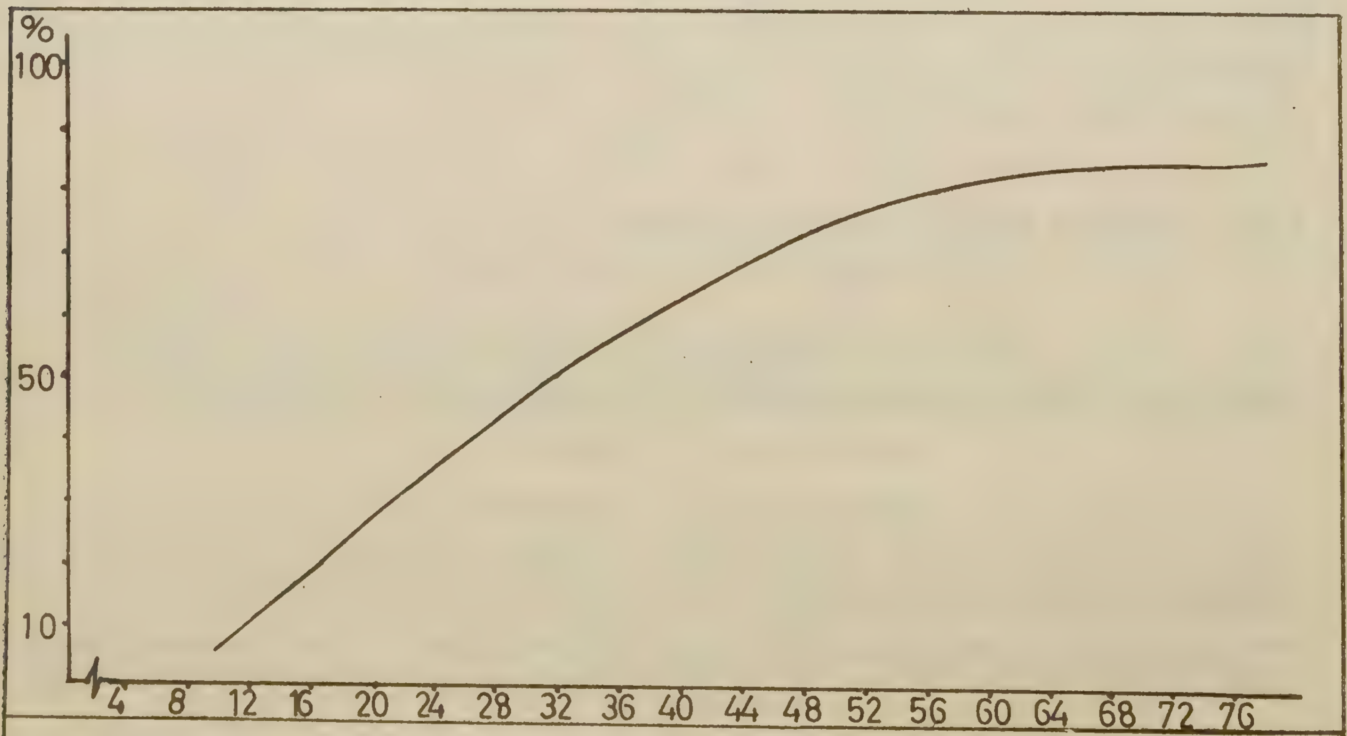

Fig. 8 Porcentaje consumido de oxígeno durante el almacenamiento de 82,5 g (P. schmitti) en un tanque de 190 litros.

b) a fin de mantener en cada estanque un número de camarones destinados al cultivo, se debe proporcionar un volumen en litros igual al número de ejemplares multiplicado por 40 (volumen por ejemplar);

c) se deben extraer todos los días los ejemplares muertos, los recién mudados y los débiles;

Ejemplo: si queremos mantener 10 camarones, se debe tener un tanque de 400 l de capacidad, el cual debe poseer un volumen de ventilación o agua circulante que proporcione 40 l/h o en otro caso un difusor de aire que mantenga oxigenada constantemente el agua, para ofrecer un habitat semejante al óptimo de los camarones.

Antes de decidir el número de camarones a colocar en el tanque, debemos conocer:

i) capacidad del tanque; ii) oxígeno disuelto en el agua en mililitros de oxígeno por litro; iii) talla promedio a almacenar; iv) temperatura del agua de mar; v) volumen de ventilación o fluidez del agua; vi) consumo de oxígeno promedio de los ejemplares (un camarón de 16,1 g consume el 35% del oxígeno en un volumen de 40 litros de agua en 24 horas).

8 CONCLUSIONES

1) El índice metabólico (microlitros de oxígeno por gramo húmedo a la hora) se incrementa con el peso de los ejemplares.

2) La correlación existente entre el peso de los ejemplares y el consumo de oxígeno es directa.

3) Para calcular el índice de utilización de P. schmitti se debe utilizar la ecuación:

$$Q\ 25^{o} = 16{,}75\ W^{0{,}992151}$$

4) La utilización del oxígeno es inversamente proporcional al peso, expresado en gramos húmedos.

5) Los ejemplares mayores poseen un metabolismo más activo debido a la complejidad de sus funciones.

6) Los ejemplares más grandes poseen un volumen de utilización de calorías/g/h mayor que el de los más pequeños.

7) El consumo de carbohidratos oscila entre 175 y 450 mg/h para los ejemplares estudiados.

8) Ejemplares mayores consumen más energía al día.

9) El trabajo realizado por los camarones utilizados fue de 800 a 2.000 joules/h lo que es necesario para obtener un eficiente consumo de oxígeno.

10) El volumen de ventilación de 9 l/h a 20°C, a 55,9 ml/g/h para ejemplares de un peso promedio de 16,1 g es el representado para P. schmitti.

11) Las mejores condiciones de vida para P. schmitti las encontramos en las salinidades entre 25 a 40 $^{0}/_{00}$.

12) La ecuación para calcular el consumo de oxígeno durante el almacenaje es:

$$Q\ 24^{o} = 0{,}21\ T^{0{,}93}$$

13) El consumo de oxígeno de un ejemplar durante su almacenamiento no debe exceder del 35% del oxígeno total del volumen de agua para que su metabolismo no se altere.

14) Cada camarón para su almacenamiento debe disponer de 40 litros de agua de mar al día.

15) Un ejemplar de un peso medio de 16,1 gr consume el 35% del oxígeno disuelto en 40 litros de agua, en 24 horas.

16) No obstante las conclusiones presentadas en este trabajo, es nuestro propósito continuar con nuevas experiencias, a diferentes temperaturas y ampliar las ya obtenidas que nos permitan corroborar todo lo tratado.

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PENAEID SHRIMP CATCH AND HEAT SUMMATION, AN APPARENT RELATIONSHIP

by

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Abstract

Commercial catches of penaeid shrimps in the southeastern United States fluctuate seasonally and annually in patterns indicating dependence on warm environment. Evaluation of annual catch-effort indexes from North Carolina, South Carolina, Georgia, and Texas (states in which species composition is mixed), treated as dependent on summation of coastal air temperatures expressed as net heating degree days, indicates an apparent association of warm years with good catches and cold years with poor catches. This relation is statistically significant for states at the geographic extremes and for all states combined. Annual catch-effort indexes treated as dependent on four types of heat summation, calendar year, calendar year plus preceding six months, heating year (1 July to 30 June), and preceding six coldest winter months, all show similar results. Real differences exist among the four geographic levels reflected in highly significant statistical differences. Use of winter temperatures as predictors for the succeeding annual catch may be possible when better estimates of effort are available.

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RAPPORT APPARENT ENTRE CAPTURES DE PENAEIDAE ET SOMMES DE TEMPERATURES

Résumé

Les captures commerciales de Penaeidae dans le Sud-Est des Etats-Unis d'Amérique manifestent des fluctuations saisonnières et annuelles dont la courbe indique qu'elles sont liées à la chaleur du milieu. D'après une étude des indices annuels prises/effort de pêche de la Caroline du Nord, de la Caroline du Sud, de la Géorgie et du Texas (Etats dans lesquels la composition par espèces est mélangée), rapprochés du bilan des températures de l'air (à des stations côtières) exprimé en "degrés-jours" nets, les années chaudes semblent correspondre à de bonnes prises et les années froides à de mauvaises. Ce rapport est statistiquement significatif pour les Etats situés aux extrêmes géographiques et pour l'ensemble de tous les Etats. Les indices annuels prises-effort, étudiées par rapport à quatre bases de bilan des températures : année civile, année civile augmentée des 6 mois précédents, "année de chauffage" (1er juillet - 30 juin), et les 6 mois les plus froids de l'hiver précédent, donnent tous des résultats analogues. Il existe des différences réelles entre les quatre niveaux géographiques, qui se reflètent dans des différences statistiques hautement significatives. Il sera peut-être possible d'employer les températures d'hiver comme indicateurs des captures de l'année suivante lorsqu'on disposera de meilleures estimations de l'effort de pêche.

LA CAPTURA DE PENEIDOS Y LA SUMA TOTAL DE CALOR: RELACION APARENTE

Extracto

Las capturas comerciales de peneidos en el sudeste de los Estados Unidos fluctúan estacional y anualmente, con características que indican que hay dependencia de un ambiente cálido. La evaluación de los índices de captura-esfuerzo anuales de Carolina del Norte, Carolina del Sur, Georgia y Texas (Estados en los que está mezclada la composición por especies), tratados como dependientes de la suma de las temperaturas del aire en la costa, expresadas como días con un grado de calentamiento neto, indica que existe una relación aparente de años cálidos con buenas capturas y años fríos con malas capturas. Esta relación tiene importancia estadística para los Estados en los extremos geográficos y para todos los Estados juntos. Los índices de captura-esfuerzo anuales, tratados como dependientes de cuatro tipos de suma de calor, o sea, año civil, año civil más los seis meses anteriores, año calórico (1 julio - 30 junio) y los precedentes seis meses del invierno más fríos, todos dan resultados análogos. Existen diferencias reales entre las cuatro zonas geográficas que se revelan como diferencias estadísticas de gran importancia. Cuando se disponga de mejores estimaciones del esfuerzo, será posible emplear las temperaturas del invierno para predecir la captura anual sucesiva.

1 INTRODUCTION

Three species comprising the bulk of commercial shrimp catches in southeastern United States (Penaeus setiferus (Linn.), white shrimp; P. duorarum Burkenroad, pink or spotted shrimp; and P. aztecus Ives, brown shrimp) are broadly understood with respect to details of life history, ecology, and geographic distribution (Williams, 1965). They are of paramount economic interest (Kutkuhn, 1962), have been tabulated in "Fishery Statistics of the United States" for years, and are subjects for active biological investigations.

Commercial catches of Penaeus species in the southeastern United States vary annually in patterns reflecting life cycles and suggesting apparent relationships to population density. Primarily tropical and subtropical in distribution, the apparent northern breeding limit is Cape Hatteras in the western North Atlantic near the 35th parallel in waters influenced to some degree by the northward flowing Gulf Stream. The pattern of geographic distribution shows dependence of these species on warm environments, and the discussion following indicates possible evaluation of this adaptation in accounting for apparent levels of abundance.

North Carolina shrimp catches, from the northern extreme of the fishery, are among the smallest for any state involved and because of climatological associations may be indicators for a fundamental factor in year-class success. Between 1950 (earliest year in which reliable catch records are available) and 1964, annual shrimp catches from North Carolina (Fig. 1) showed a seesaw variation with a mean of about 4 million lb or 1.8 million kg (headless). The first 8 yr of this period included catches mostly exceeding this level, but catches since then have fallen short.[1] The greatest catch occurred in one of the warmest years, 1953; poorest catches were in the cold years, 1958, 1961 and 1963. Such patterns support the idea that temperature may influence catch, and there is ample evidence to document destructive effects of low winter temperatures on overwintering shrimp (Gunter and Hildebrand, 1951; Lindner and Anderson, 1956; Joyce, 1965). The relation shown in Fig. 1 further suggests that warm years may be as beneficial as cold years are deleterious, warm years at the northern extreme of breeding range tending toward optimal environmental temperatures for the species, hence reflecting higher yield.

2 METHODS

Ten years ago, the author attempted to correlate temperature with shrimp catch in North Carolina (Fig. 2) during the early 1950's by using average monthly air temperatures from five land-based weather stations along the coastal counties. Air temperatures were chosen because adequate water temperature records were not available; however, temperatures in the shallow coastal embayments closely follow air temperatures (Roelofs and Bumpus, 1953; Williams, 1955), an effect commonly recognized elsewhere. Results were inconclusive and analysis was deferred until more data were available. After the winter of 1958, when ice covered much of the North Carolina sounds for the first time since 1918, and after the somewhat different but colder than normal winters of 1961 and 1963 (Carney, 1958; Hardy, 1961; 1963), data representing extreme as well as more normal years began to be available for analysis.

Averages do not adequately represent extremes, since they tend to mask duration or intensity. A method which would give weight to these factors and yield easily analyzed measurement of temperature was offered by the U.S. Weather Bureau summation of heating degree days. This type of summation, evaluated by Allee, et al. (1949), and Andrewartha and Birch (1954), seemed adaptable to the present problem.

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[1] U.S. Department of Interior, Fish and Wildlife Service, Statistical Digests 27, 30, 34, 36, 39, 41, 43, 44, 49, 51, 53, 54, 56, 57, Fishery Statistics of the United States, 1950-63.

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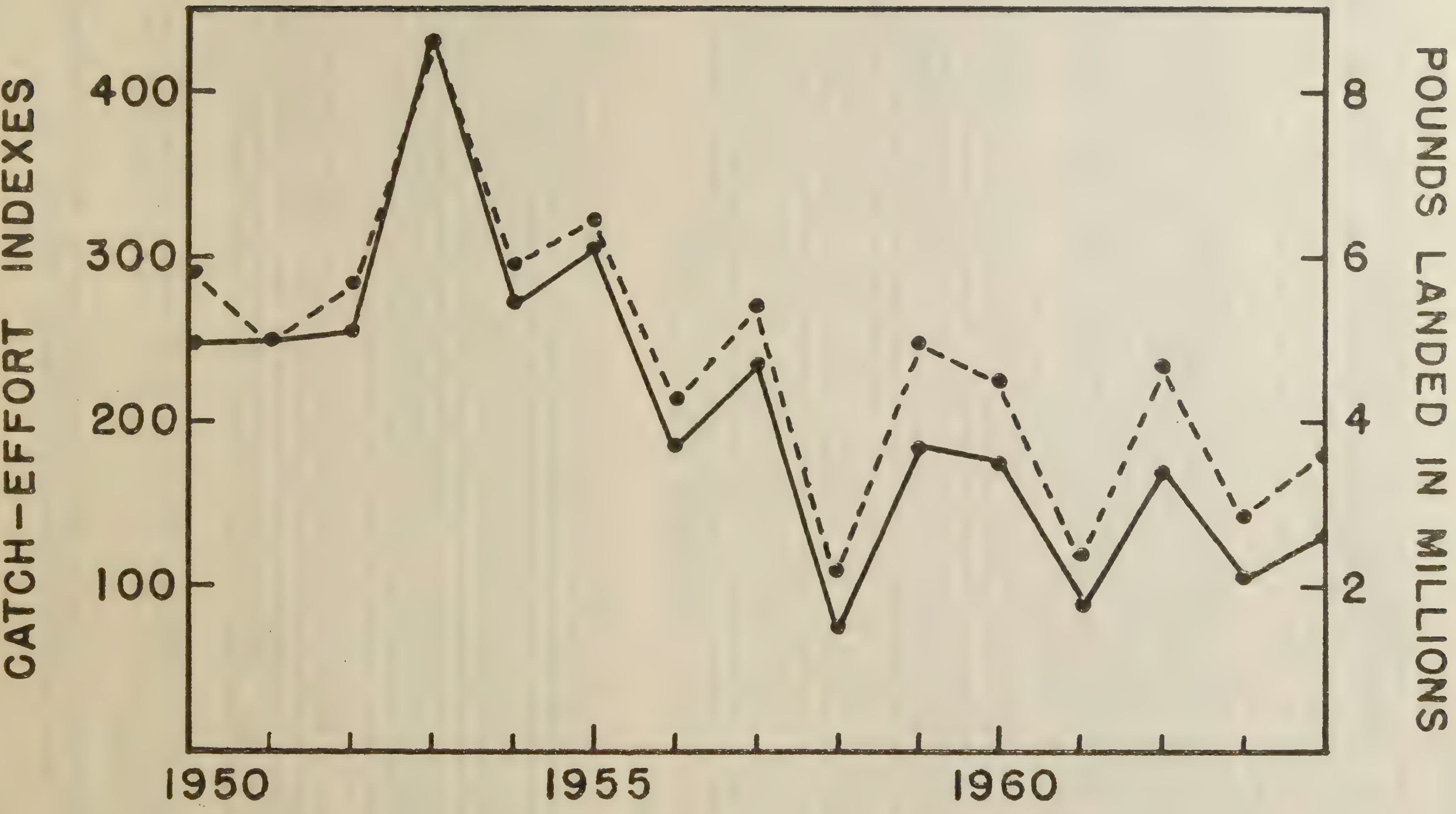

Fig. 1 Annual shrimp catch in North Carolina from 1950 to 1964 based on headless poundage (weight of edible abdomens only). Solid line represents catch-effort indexes. Broken line represents millions of pounds landed.

In this summation, the base temperature for calculation is 65°F (18.3°C).[2] Average of maximum and minimum temperature for a 24-hour period is computed, and, if below 65°F, is recorded as heating degree days. (Example: max 65°F (18.3°C), min 55°F (12.8°C); $\bar{x}$ = 60°F (15.5°C) = 5 heating degree days). The Weather Bureau sums these for each heating year, 1 July to 30 June, at selected stations. By using Weather Bureau data from an appropriate near-shore weather station, suitable cold weather data for shallow water areas are available when actual water temperature records are inadequate or nonexistent. For warmer days, the converse of Weather Bureau heating degree days can be computed as negative heating degree days. (Example: min 65°F (18.3°C), max 75°F (23.9°C); $\bar{x}$ = 70°F (21.1°C) = -5 heating degree days). In this analysis, any arbitrary scale will serve equally well. Net heating degree days were computed from daily temperatures for 1950-64 on a monthly basis (U.S. Weather Bur., 1950-64).

Cape Hatteras weather station was chosen as the reference for North Carolina temperature data. The station is located centrally on the coast near shrimp fishing grounds in Pamlico Sound and immediate coastal waters.

Although preliminary correlation of net heating degree days with total catch in North Carolina appeared promising, some indication of fishing effort was thought necessary, in order to reduce error. From published statistics, only "yards trawl at mouth" gives any indication of effort. Therefore, total pounds (headless) landed annually divided by yards trawl at mouth for that year can provide a rough catch-effort index (Fig. 1). This index is the dependent variable in the following analyses. However, the quantity, pounds landed, almost parallels the indexes and in this case would serve as well. No weight is given to such factors as "standard fishing days", as this refinement is beyond our ability to estimate at present.

With temperature and catch-effort data in hand, the following four postulated relationships may be evaluated, each based on annual life cycles of the three species of shrimp.

(1) Annual catch may depend on net heating degree days for the calendar year during which the catch was made. Certainly, activity of shrimp during the fishing season may depend on such.

(2) If net heating degree days have any possible connection with a year's catch and are meaningful, temperatures for a calendar year plus the preceding six months must be considered, in order to evaluate effects of temperature on autumnal recruits harvested the following spring.

(3) Again, some shrimp caught in one calendar year are spawned during the last half of the preceding year. If effect of temperature is most pronounced during early life, a valid relationship may be that one calendar year's catch is dependent on net heating degree days accumulated during the preceding heating year.

(4) Cold of winter may have more direct and indirect effects on catch than warm periods of the year. Therefore, catch for a calendar year may depend on net heating degree days during the coldest preceding six months, e.g. November to April of the preceding winter.

With these propositions (independent variables) set forth, data for a series of regression analyses of North Carolina catches were prepared for analysis by the University of North Carolina Computation Center. Similar catch-effort data from the

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[2] Weather Bureau data include the term "degree days (base 65°F)" herein termed "heating degree days". Biological literature contains the terms "day degrees" or "hour degrees" with different bases.

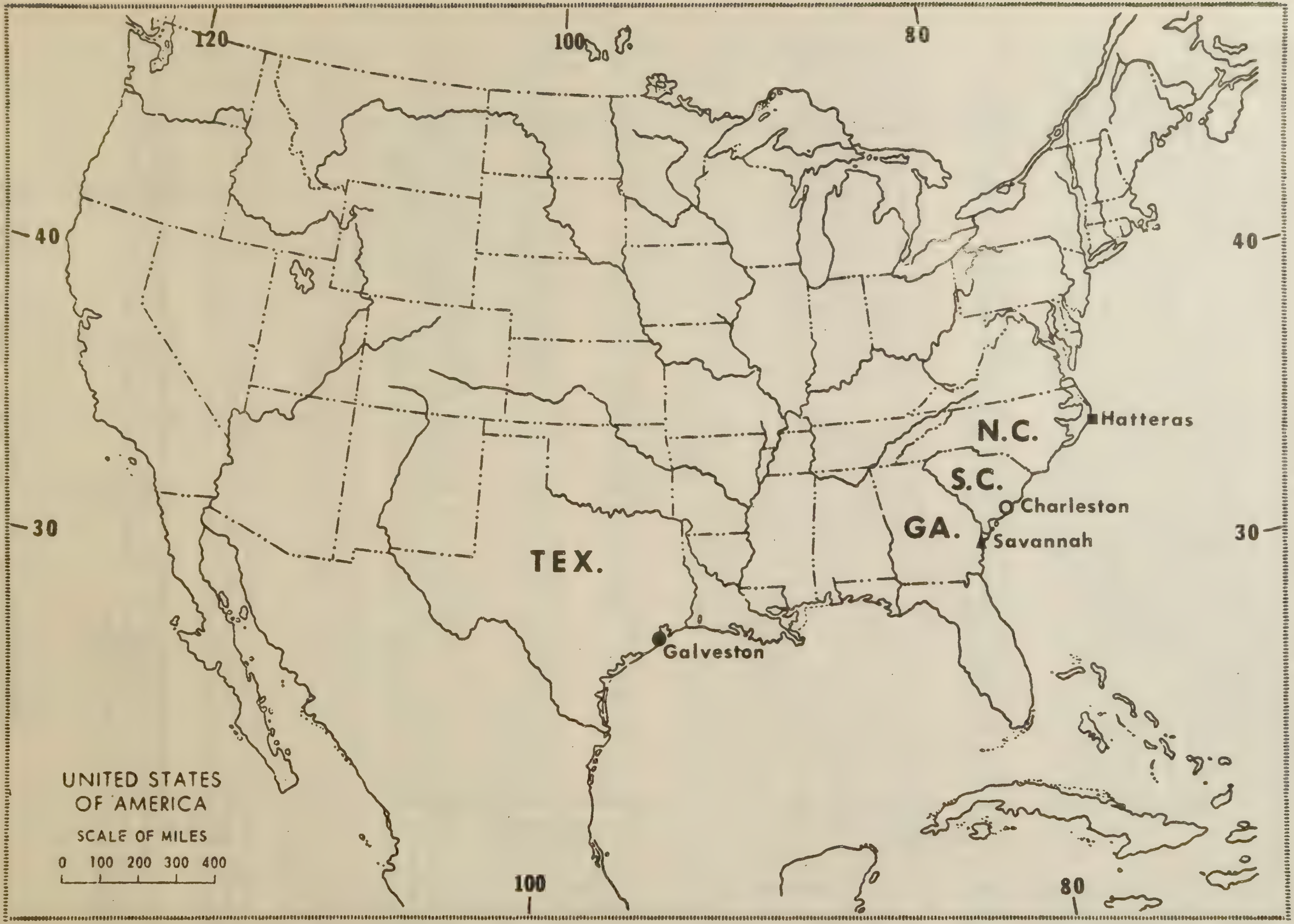
120
100
80
40
40
30
30
100
80
Hatteras
N.C.
S.C.
Charleston
GA.
Savannah
TEX.
Galveston
UNITED STATES
OF AMERICA
SCALE OF MILES
0 100 200 300 400

Fig. 2 Map of United States of America showing four states, North Carolina, South Carolina, Georgia, and Texas, with reference points for temperature data, Hatteras, Charleston, Savannah, and Galveston.

following areas were subjected to similar analyses: South Carolina (temperature records from Charleston), Georgia (temperature records from Savannah) and Texas (temperature records from Galveston); the wide separation of Texas from the other areas should be noted. If any of the propositions proved to be statistically valid for North Carolina (Fig. 2), where effects of temperature might be most pronounced, they might be statistically valid for milder areas having shrimp populations composed of the same species; however, it is granted that error might be introduced by latitudinal differences in recruitment time and proportional differences in species composition.

Individual regression analyses at each geographic level and combined geographic levels were made for each proposition. Finally, each proposition was subjected to covariance type analysis giving a common slope to each geographic level but a different intercept to each.

3 RESULTS

When data from all geographic locations are considered together, large numbers of negative net heating degree days (warm temperatures) tend to be associated with large catches, and, conversely, large numbers of positive net heating degree days (cool temperatures) tend to be associated with small catches (Figs. 3, 4, 5, 6). Moreover, this trend is apparent within each of the four geographic levels, although upper and lower limits of each level are necessarily more restricted than the total. Texas shows the largest catches, and these are associated with the largest totals of negative heating degree days. At the opposite end of the trend, North Carolina shows the smallest catches, and these are associated with the largest totals of positive heating degree days. An indifferent and rather broad scatter of points characterizes the intermediate levels, South Carolina and Georgia.

Results of analyses in accordance with the four propositions are summarized in Table I. All regressions for Hatteras are statistically significant. Those for Galveston are also significant ($P < .05$), with the exception of catch dependent on calendar year ($P < .10$). Regressions for South Carolina and Georgia are not statistically significant. However, the scatter of points is such that combined geographical data for each proposition is highly significant.

An analysis of covariance type adjustment in which the intercepts are different for the four geographic levels while the slope remains constant for all is summarized in Table II. For each proposition there are real differences among geographic levels reflected in highly significant statistical differences. This fact seems obvious, because the regression lines reflect geographic distributional patterns with a southern center of dispersal and peripheral, less dense populations to the north. Though the trends support such an idea, order of elevation of the intercepts appears contradictory. It would appear that there should be an orderly low to high progression of intercepts from Hatteras to Galveston.

4 DISCUSSION

Distribution of marine organisms along coasts of the United States may be governed by optimum temperatures for reproduction and growth to maturity, as suggested for certain molluscs (Hall, 1964). Also, as Gunter (1957) pointed out, the temperature norm for most species is a set of varying conditions and this set may represent an optimum. Nevertheless, fluctuations in apparent population size among well-known species occur where temperatures vary and where optimal sets of conditions are as yet unassessed.

Fluctuations in shrimp production, as reflected in annual catches, have been attributed to both rainfall and temperature. Effects of rainfall analyzed statistically (Hildebrand and Gunter, 1953; Gunter and Hildebrand, 1954) suggested that catches of P. setiferus could be positively correlated with rainfall in Texas. ' Although such relationship has not proved statistically significant in North Carolina (based on the years 1950 to 1955), effect of heavy rainfall on movements of estuarine, juvenile, and

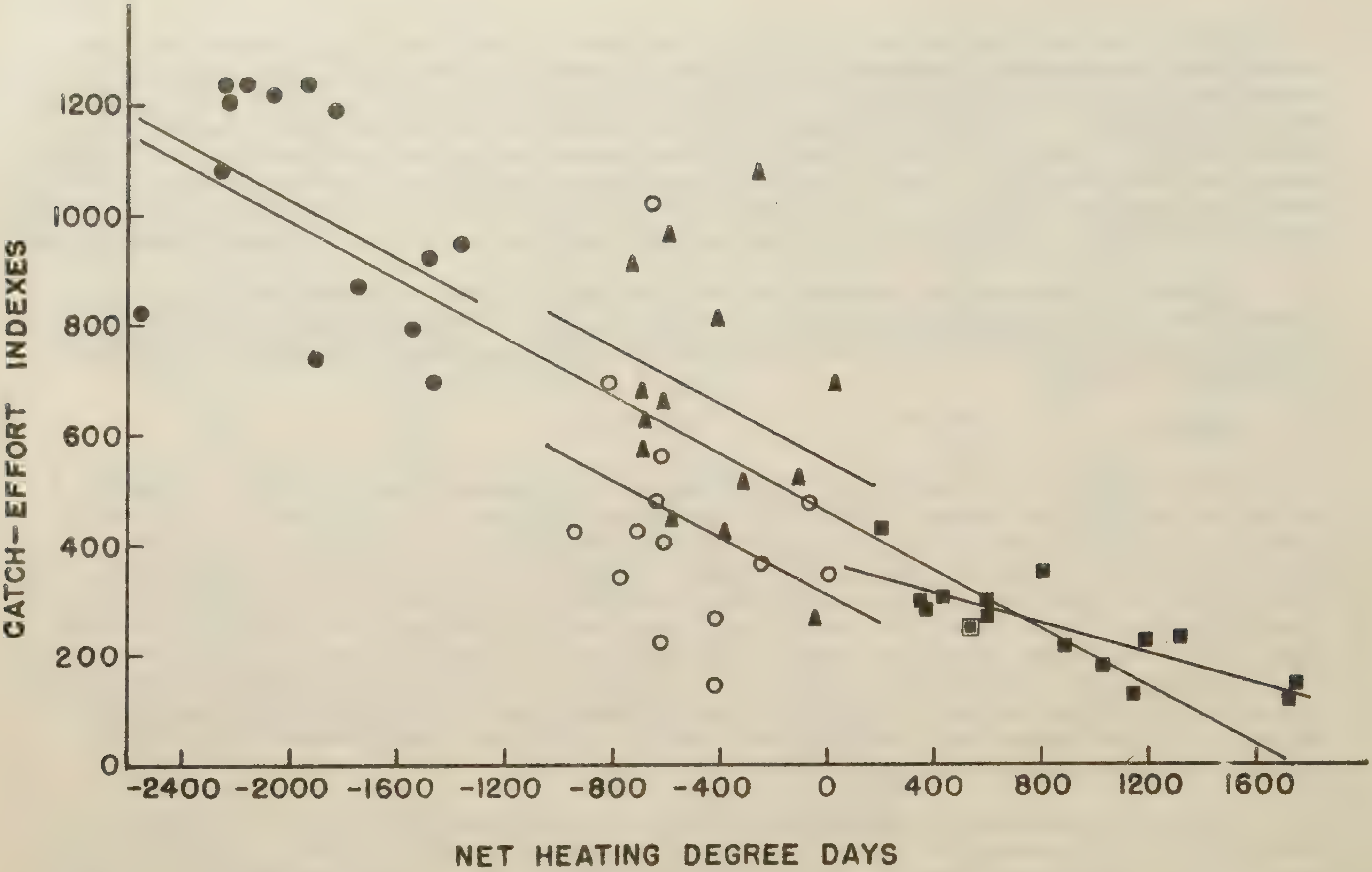

Fig. 3 Annual shrimp production as catch-effort indexes plotted against net heating degree days per calendar year. Four geographic levels represented by four short regression lines: Hatteras ■ (1950-64); Charleston ○ , Savannah ▲ , Galveston ● (1950-63). Long line represents pooled data.

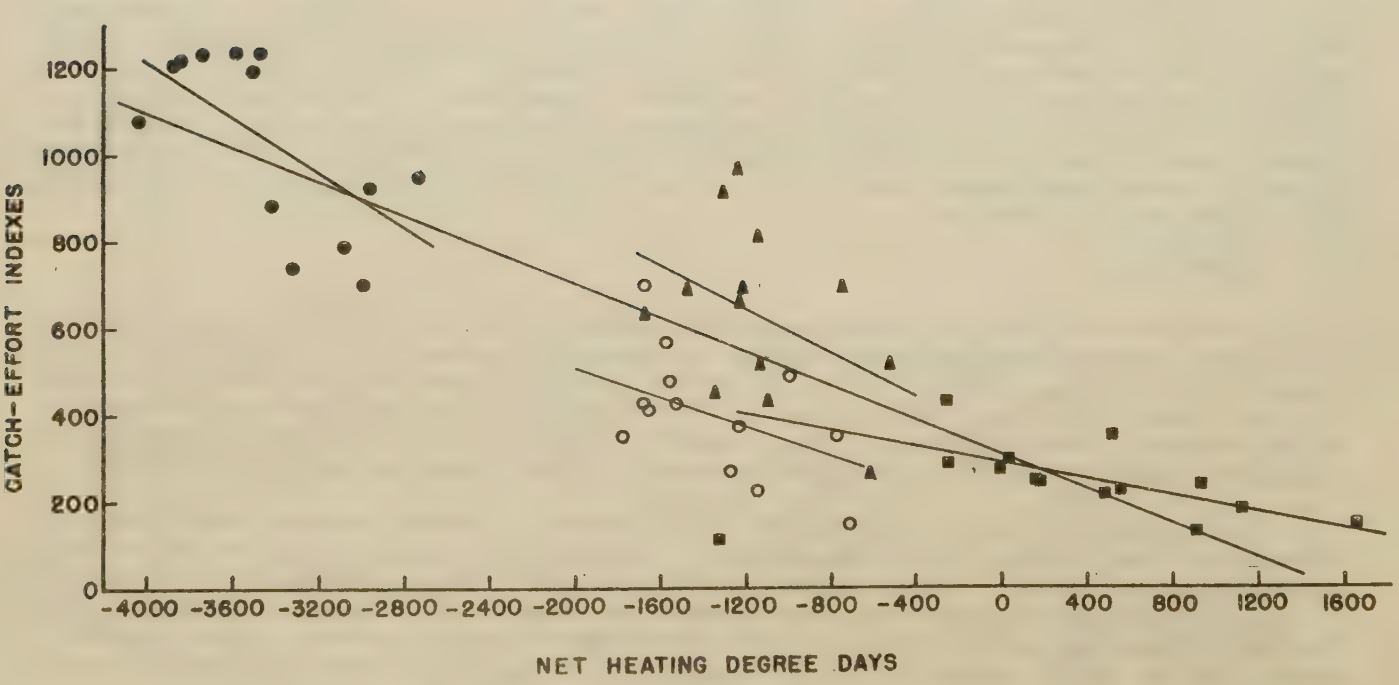

Fig. 4 Annual shrimp production as catch-effort indexes plotted against net heating degree days for calendar year plus preceding six months. Four geographic levels represented by four short regression lines: Hatteras ■ (1950-64); Charleston ○ , Savannah ▲ , Galveston ● (1950-63). Long line represents pooled data.

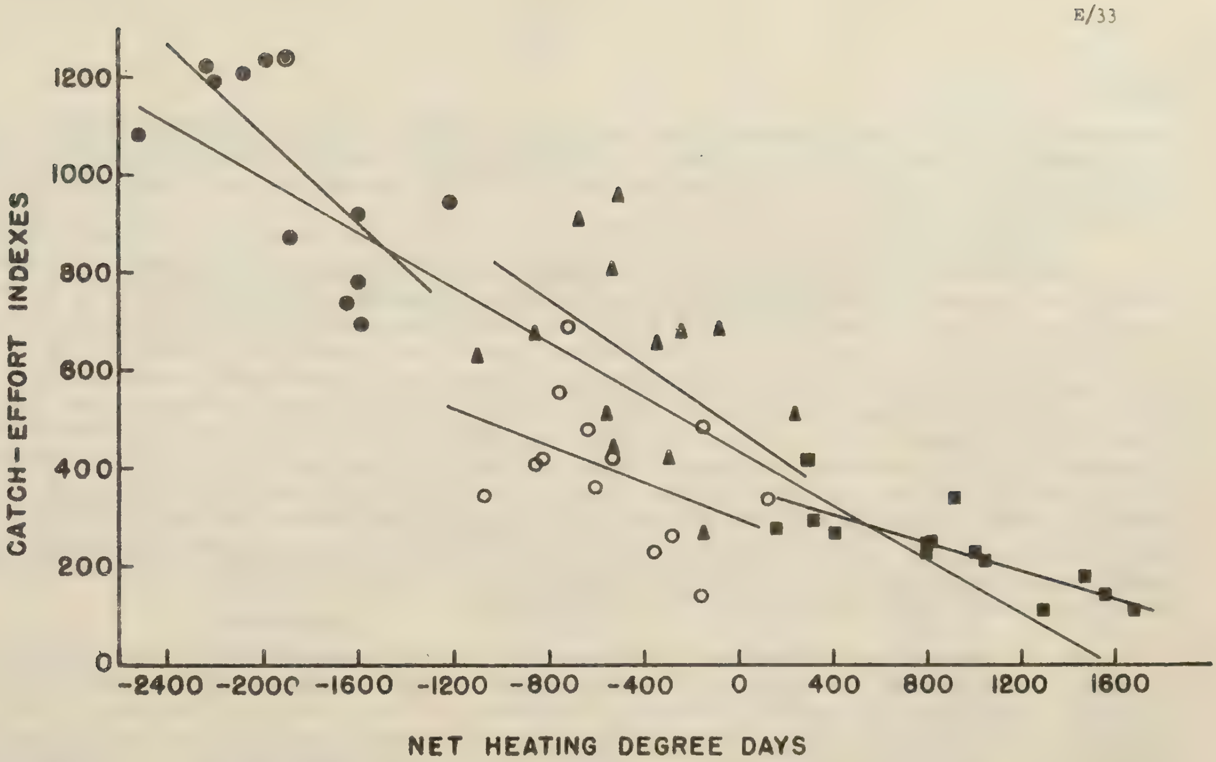

Fig. 5 Annual shrimp production as catch-effort indexes plotted against net heating degree days per heating year (1 July - 30 June). Four geographic levels represented by four short regression lines: Hatteras ■ (1950-64); Charleston O, Savannah ▲, Galveston ● (1950-63). Long line represents pooled data.

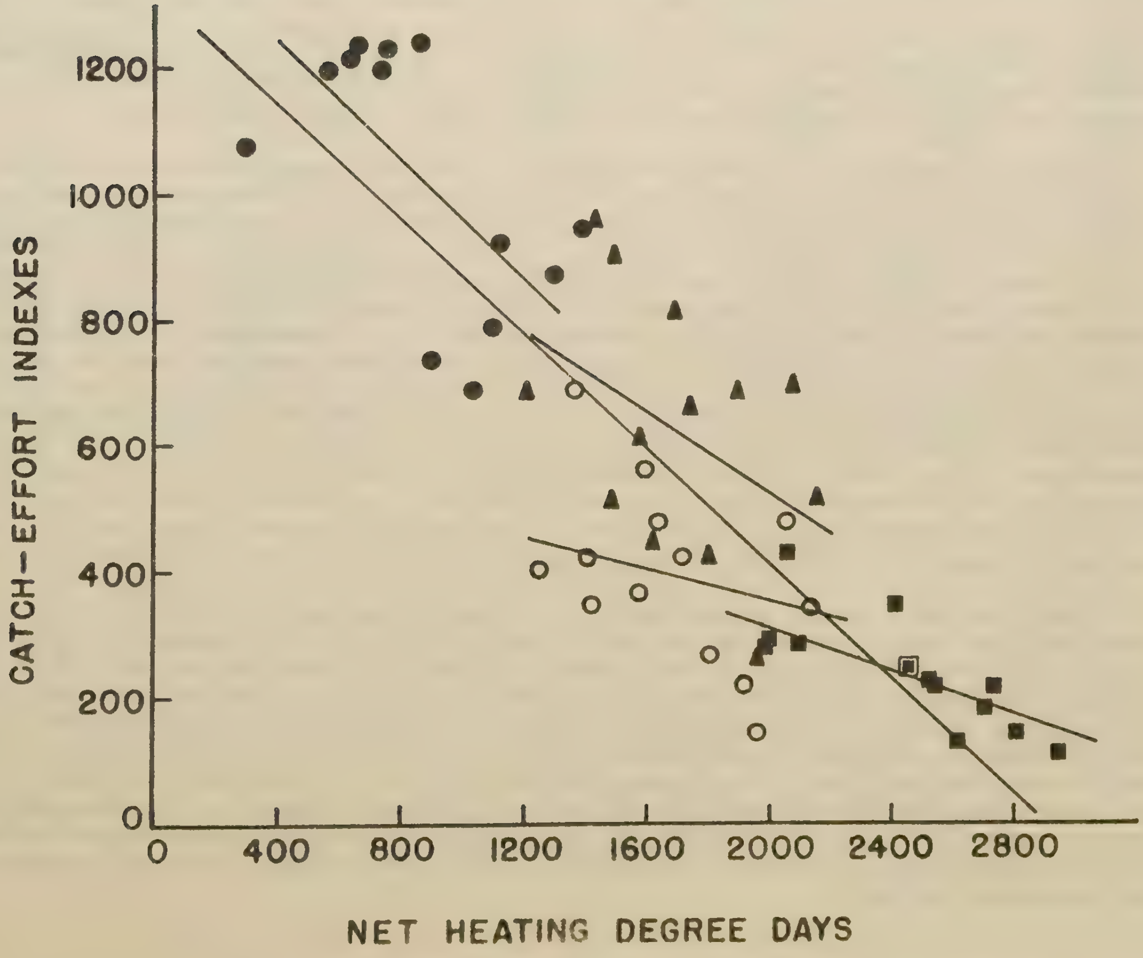

Fig. 6 Annual shrimp production as catch-effort indexes plotted against net heating degree days in preceding six cold months (November-April). Four geographic levels represented by four short regression lines: Hatteras ■ (1950-64); Charleston O, Savannah ▲, Galveston ● (1950-63). Long line represents pooled data.

subadult shrimp is well known (Tabb and Jones, 1962; personal observations). Effects of temperature are also recognized. Hildebrand and Gunter (1953) considered such data too nebulous for fruitful discussion, but felt that demonstrable relationships merely awaited amassing sufficient data.

Dependence of P. setiferus, P. duorarum, and P. aztecus on a moderate temperature range for optimum living conditions is widely recognized and documented by experiment and observation. Zein-Eldin and Aldrich (1965) found postlarval P. aztecus surviving temperatures as low as 11°C with almost no growth per month in salinities of about 15 $^{o}/_{oo}$ or above. Significant growth began between 11° and 25°C. Below 15°C, postlarvae showed decreased tolerance to low salinity. The authors speculated that natural distribution and survival of these new recruits from the sea in estuaries is governed by temperatures in spring, with salinity per se having no effect on survival or growth except at extreme temperatures. St. Amant, Corkum and Broom (1963) attributed cyclic movements and densities of P. aztecus postlarvae to control by hydrographic and meteorological conditions in spring. Appearance of postlarvae in abundance was associated with water temperatures greater than 20°C, and rapidity of growth increased markedly above this to summer temperature levels.

It is common knowledge among students of the subject that growth among these three species of penaeids is more rapid in warm than in cold seasons. Numerous estimates concur on growth rates among juveniles of about .05 to 1 mm in total length per day during warm weather in the United States (perhaps less in certain areas, Kutkuhn, 1966), and there is agreement that these rates are depressed during winter. It follows that temperature directly or indirectly influences growth and survival of these species (see Introduction) and thus has an effect on gross production as reflected in catch. One may then ask in what way may catch be made meaningful in terms of temperature? If such relationship can be demonstrated, is it descriptive for a restricted, possibly marginal area of the species' geographic range, or is it general over the latitudes influenced by continental climate treated here? All of these questions were considered in preparation of the analyses. When it became apparent that a good relationship existed between temperature summation and shrimp catch in North Carolina, it seemed logical to extend the query to other areas with somewhat similar mixed populations.

From the analyses, it seems that each of the four propositions has validity. The closest statistical relationship appears to be annual catch dependent on net heating degree days in a heating year; this treatment yields the lowest error (Table I).

Although a good fit of catch with heating year may be historically instructive, a step toward prediction might be possible through another of the postulated relationships. Prediction must be made early in a year to be useful. Therefore, among hypotheses considered here, net heating degree days during winter months are the only useful basis for prediction of catch in a calendar year. For winter in North Carolina, one can even ignore net heating degree days and use only heating degree days as summed by the Weather Bureau with results and margin of error comparable to methods employing net heating degree days. Thus, catch-effort indexes dependent on heating degree days in the preceding six cold months, November to April, yields $y = -.217X + 771.22$ ($s_{x.y} = 56.56$, $P < .01$) for Hatteras during 1951 to 1964. But heating degree days alone for the more southerly localities, treated similarly, yield statistically non-significant results.

Data for South Carolina and Georgia are unsatisfactory in that none of the regressions for these localities are statistically significant, though it is clear from pooled data that they lie along the trend. It is felt that statistics for effort in those states during the years studied are not comparable to similar data from North Carolina and Texas. Indeed, the great shortcoming seen in all data presented here lies in lack of accuracy in assessing effort. In comparisons among states on the Atlantic seaboard and Texas, where more refined records are available (Kutkuhn, 1962), the least accurate effort data had to serve in forming indexes. If this aspect of the records collected could be refined, it is felt that error could be reduced to the point that more meaningful prediction of annual catch might be based on heat summation during the preceding winter.

TABLE I

Catch-effort indexes dependent on four kinds of net degree-day summations at four geographic levels: 5% level accepted as statistically significant

Net degree-day summation	Locality	Intercept	b	$s_{x \cdot y}$	P
Calendar year	Hatteras	364.53	-.139	53.22	$<.01$
	Charleston	308.15	-.261	211.32	ns
	Savannah	555.72	-.259	221.27	ns
	Galveston	472.47	-.284	190.49	$<.10$
	Combined	459.81	-.267	197.11	$<.01$
Calendar year plus preceding 6 months	Hatteras	291.50	-.096	63.52	$<.01$
	Charleston	169.51	-.169	135.37	ns
	Savannah	345.04	-.251	184.20	ns
	Galveston	-53.50	-.317	165.96	$<.05$
	Combined	311.90	-.196	176.99	$<.01$
Heating year	Hatteras	370.33	-.144	54.80	$<.01$
	Charleston	301.46	-.191	137.84	ns
	Savannah	487.23	-.338	179.58	ns
	Galveston	177.74	-.456	155.40	$<.01$
	Combined	444.54	-.277	175.68	$<.01$
Preceding 6 cold months	Hatteras	669.51	-.177	67.50	$<.01$
	Charleston	610.79	-.128	146.72	ns
	Savannah	1,168.37	-.320	185.47	ns
	Galveston	1,439.64	-.477	162.32	$<.05$
	Combined	1,330.54	-.456	185.03	$<.01$

TABLE II

Geographic levels given a common slope for each independent variable (covariance analysis). High statistical significance exceeding the 1% level indicates magnitude of difference in y intercepts for geographic levels

Net degree-day summation	Locality	Intercept	b	$s_{x \cdot y}$	P
Calendar year			-.210	176.84	<.01
	Hatteras	426.19			
	Charleston	334.39			
	Savannah	575.69			
	Galveston	614.02			
Calendar year plus preceding 6 months			-.175	145.28	<.01
	Hatteras	333.22			
	Charleston	161.61			
	Savannah	431.28			
	Galveston	432.67			
Heating year			-.244	141.71	<.01
	Hatteras	461.26			
	Charleston	274.72			
	Savannah	526.73			
	Galveston	574.26			
Preceding 6 cold months			-.270	146.98	<.01
	Hatteras	894.91			
	Charleston	847.12			
	Savannah	1,084.21			
	Galveston	1,262.20			

Temperature summation is chiefly a useful indication at this stage of analysis. Correlations of catch with rainfall, levels of pollution, or a number of such environmental influences considered together may prove useful enough in prediction that monitoring programs will become practical.

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A DESCRIPTIVE AND ANALYTICAL MODEL OF THE SHARK BAY PRAWN FISHERY

by

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Abstract

The fishable life span of Penaeids is normally not more than about one year and so the catch for a particular year depends upon the recruits entering the fishery just prior to or during that year. The basic requirement for management is the knowledge of variations in the timing and strength of this recruitment.

Fishery models examined are primarily based on fin fisheries of the North Atlantic and are inadequate for Western Australian penaeid fisheries. The basic assumptions on recruitment, age estimation, growth pattern and effect of migration are inapplicable.

A model is proposed based on the use of detailed data on catch, effort and size composition of catches. This model distinguishes between the effects of growth, migration and variation in density with time. It provides a means of examining time, place and strength of recruit groups entering the fishery.

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UN MODELE DESCRIPTIF ET ANALYTIQUE DE LA PECHERIE DE CREVETTES DE LA BAIE DU REQUIN

Résumé

Etant donné que normalement la durée de vie exploitable des Peinaeidae ne dépasse pas un an environ, les captures pour une année donnée dépendent du nombre de recrues entrant dans la phase exploitable juste avant ou pendant cette année. Il est donc indispensable, aux fins de l'aménagement, de connaître les variations survenant dans l'époque et dans l'importance de ce recrutement.

Les modèles halieutiques étudiés reposent principalement sur les pêcheries de poissons de l'Atlantique Nord et ne conviennent donc pas aux pêcheries de Penaeidae de l'Australie-Occidentale. Les hypothèses de base sur le recrutement, l'estimation de l'âge, le schéma de croissance et les effets des migrations ne sont pas applicables.

Il est proposé un modèle reposant sur l'emploi de données détaillées sur les captures, l'effort de pêche et la composition par taille des prises. On y distingue entre les conséquences de la croissance, des migrations et des variations de densité avec le temps. Ce modèle fournit un moyen d'examiner l'époque, le lieu et l'importance du recrutement.

UN MODELO DESCRIPTIVO Y ANALITICO DE LA PESQUERIA DE CAMARONES DE LA BAHIA SHARK

Extracto

La duración de la vida pescable de los peneidos por lo general no es superior a un año aproximadamente y por esto la captura que pueda hacerse en un año determinado depende de los individuos que se incorporen a la pesquería exactamente antes de dicho año o durante él. El requisito básico para la ordenación es conocer las variaciones en cuanto al momento de verificarse el reclutamiento y a la intensidad del mismo.

Los modelos pesqueros examinados se basan primariamente en las pesquerías de peces del Atlántico norte, siendo inadecuados para las pesquerías de peneidos de Australia occidental. Son inaplicables los supuestos básicos sobre reclutamiento, estimación de la edad, tasa de crecimiento y efectos de la migración.

Se propone un modelo basado en el empleo de datos detallados sobre captura, esfuerzo y composición por tamaño de las capturas. Este modelo diferencia entre los efectos del crecimiento, la migración y la variación en densidad con el tiempo. Proporciona un medio para examinar la época, lugar e intensidad de los grupos de individuos que se incorporan a la pesquería.

1 INTRODUCTION

Responses to changes in exploited populations are in general the result of a number of contributing responses, many not directly measurable. This makes a complete understanding of the systems involved extremely difficult. Models are simplified representations of these complex systems that (i) permit explanation of the observed phenomena, (ii) suggest the relationships between the significant parameters and (iii) provide a means of predicting changes that will occur within the system if the parameters are varied.

This approach is well known in fisheries science, and Beverton and Holt (1957) and Ricker (1948) have made fairly recent reviews of the literature. The models described by these workers have, however, been largely developed for teleost fisheries. Although the basic assumptions inherent in these models are upheld for prawn fisheries, certain statistics, particularly age, are difficult to determine.

Direct age determination of crustaceans in the catch is not possible and hence parameters such as age of recruitment (t_r) and age of first capture (t_c) from teleost models are not applicable. Size-age relationships are found only indirectly (Burkenroad, 1951; Kurata, 1962). In addition, growth as measured by increases in external size is not continuous but takes place in a series of steps, each step occurring at moulting (Passano, 1960). Growth models commonly used (Von Bertalanffy, 1938; Parker and Larkin, 1959) are based on continuous growth, and these apply to crustacea only if size is assumed to increase during the intermoult. It has been found in most cases that these models empirically fit growth data, but no rigorous study has yet been made. Indeed, a form of step function may more adequately describe crustacean growth.

In teleost models, migration within the area under consideration is usually considered negligible, although Beverton and Holt (1957) propose a spawning migration model based on thermodynamic dispersal theory. A basic assumption of the population estimation model of DeLury (1947) is that migration does not occur. Penaeids are highly migratory (Weymouth, Lindner and Anderson, 1933; Lindner and Anderson, 1956; Dall, 1958; Slack-Smith, 1969) and migration is, therefore, an important parameter in penaeid populations.

A corollary to this high mobility is that recruitment must continue for an extended period if the numbers on a particular ground are to be maintained during the fishing season. Furthermore, in Shark Bay recruitment appears to be in waves, each probably associated with lunar periodicity in spawning and with later migration from prawn nursery areas (Racek, 1959; Dall, 1958).

Penaeid tagging for other than migration studies has not been entirely successful (Menzel, 1955; Dawson, 1957; Lindner and Anderson, 1956; Iversen and Idyll, 1960; Costello, 1959; Costello and Allen, 1960) although Lindner and Anderson (1956) recorded growth increments and Iversen (1962) made population estimates using Petersen tags.

In contrast to most penaeid fisheries, very detailed catch, effort and size composition data have been collected for the Shark Bay fishery (Slack-Smith, 1969; Slack-Smith and Stark, 1968). Insufficient research staff was available to prosecute a full biological programme, hence an attempt is made to use these commercial data to elucidate several biological processes within the fishery and to construct a model, initially descriptive but ultimately analytical, applicable to this population.

2 THE PROPOSED MODEL

The general features of the fishery and of methods of data collection are described by Slack-Smith (1969) and Slack-Smith and Stark (1968).

Shark Bay penaeids seldom remain in the fishable stock for more than one season. The potential yield from an area, therefore, depends directly upon recruitment just prior to and during the fishing season. Catch and effort data from the Shark Bay fishery indicate that the time and place of recruitment throughout a particular season is not constant nor is it constant from season to season (Slack-Smith, 1966; 1969). A further complication is that the magnitude of total recruitment varies from year to year.

The basic management requirement for this fishery is to determine whether these changes are random, cyclic or trending downwards. If they are the result of a downward trend the causes of the decline must be determined and methods found by which it can be halted.

Before the nature of recruitment changes can be investigated, a means of estimating recruitment must be found. A model has accordingly been constructed to investigate these and other changes within the Shark Bay fishery.

The basic data for the proposed model are obtained from a computer programme which inputs scored length frequency data, the weight of the sample from which they are made, the total landed weight and the total fishing effort for a particular week (i). Numbers caught (N_{ijk}) at each carapace length (j) are included in the output. This portion of the output is used to set up a three-dimensional array of D_{ijk} (Fig. 1) that represents densities of prawns of particular sizes on each block (k) within the fishery during each week of the season, i.e.,

$$D_{ijk} = N_{ijk}/f_{ik} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (1)$$

The normal assumption that catch per unit of effort is proportional to absolute density is not entirely valid in the Shark Bay prawn fishery. Catchability, the constant relating these parameters, varies cyclically with changes in time of day and in lunar phase. It is assumed for this model that appropriate corrections have been made to catch rates to eliminate these effects.

To simplify explanation of this model, prawns are assumed to move on a line in the direction of migration, i.e., that the fishery is one block wide and there is no lateral emigration or immigration. In the case of the Shark Bay fishery this is not so and there is undoubtedly lateral movement, necessitating the inclusion of a two-dimensional migration component when the model is being tested on fishery data. Density changes within the model are more readily observed if each modal size group within a catch-per-length-frequency (there are usually 1 to 3) is represented by the modal value or values (MCL_n). It is further assumed that these modal values always represent the densities of the whole group, i.e., there is no size selection during fishing, and the distribution around this mode remains constant.

As the season progresses, i.e., i increases (Fig. 1), each of these points of density will move through the space enclosed by the three axes of the model. The vector of this movement in i represents the time scale; the vector in j, size increase; the vector in k, migration.

2.1 Recruitment

Entry of a modal group into the model during the increase of i from o to λ (the length of the season) represents recruitment, and the associated j and k values give the modal recruit size and the area where juvenile prawns enter the fishery. The relative abundance of this recruit group is given by its MCL_n value. The MCL_n values are then summed to obtain an index of total recruitment for season s (R_s), i.e.

$$R_s = \sum MCL_n \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (2)$$

2.2 Growth and migration

Mean rate of size increase of a recruit group is represented by the rate at which the j component (growth increment) increases with time. Individual size increase is

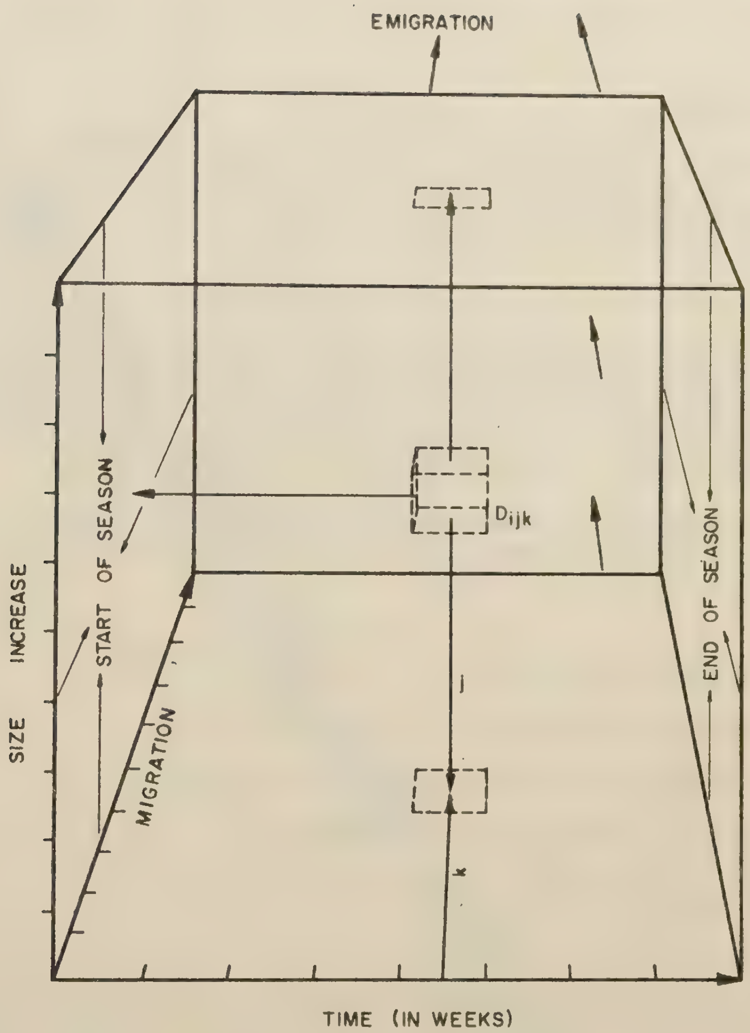
EMIGRATION
D$_{ijk}$
SIZE INCREASE
START OF SEASON
MIGRATION
END OF SEASON
j
k
TIME (IN WEEKS)

Fig. 1 Diagrammatic three-dimensional representation of the Shark Bay prawn fishery. $D_{i\,jk}$ is the density of a recruit group, MCL_n, at time i, size j and position (after migration) k.

not continuous but is stepwise (section 1). However, in this model sudden increases in mean carapace length would be observed only if all prawns moulted at the same time. But, as moulting in Shark Bay prawns has been observed at virtually all times, it appears that in practice a continuous increase in mean size will be observed.

Migration rate (m) is given by the rate at which the k component increases with time.

2.3 Total mortality

The rate of density decrease in each recruit group is given by the rate of decrease of MCL_n (Fig. 2). The Instantaneous Coefficient of Total Mortality ($Z = F + M$) can be calculated using methods described by Gulland (1965). If the abundance as given by MCL_n is N_o at a given time t_o and N_i at time t_i then

$$N_i/N_o = S = e^{-Z(t_i-t_o)} \quad .. \quad .. \quad .. \quad .. \quad (3)$$

i can be considered as a single week or any desired number of weeks. If the values for total mortality for a particular recruit group obtained from the model by equation (3) are plotted against the effort for that week, and provided the effort varies sufficiently, estimates of fishing mortality (F), natural mortality (M) and catchability (q) can be made for that group using the method described by Widrig (1954).

Prior to the construction of this model, components of migration were included in any estimate of Z made on a particular block in a similar manner, i.e.

$$Z^1 = F + M + E - I \quad .. \quad .. \quad .. \quad .. \quad .. \quad (4)$$

Where Z^1 = Instantaneous coefficient of total fall in numbers

F = Instantaneous coefficient of fishing mortality

M = Instantaneous coefficient of natural mortality

I = Instantaneous coefficient of immigration

E = Instantaneous coefficient of emigration

2.4 Emigration

Prawns lost from the fishable stock by emigration are represented by recruit groups passing through the rear face of the model. As each block in Shark Bay is a square of 10 x 10 mi, prawns migrating across the block at a rate m mi/wk will traverse m/10 of a block per wk. If the density on that block is D_{ijk}, then the number of prawns emigrating from the fishery during that week is given by the product of that density and the area occupied by those prawns (m/10).

Fishing and natural mortalities also operate during that week, the numbers lost being represented by $D_{ijk}.m/10.(1-e^{-z})$

If all these terms are summed for each week of the season the total emigration loss (E) is obtained, i.e.,

$$E = \sum D_{ijk}.m/10.\,(1-e^{-z}) \quad .. \quad .. \quad .. \quad .. \quad (5)$$

2.5 Estimation of numbers

After entering the fishery the size of a particular recruit group (R_s) is decreased by the combined effects of natural and fishing mortality (Fig. 2), where $Z = F + M$. Now, $N_i = N_o.e^{-(F + M)i}$, and if the contribution of M to total mortality is small the

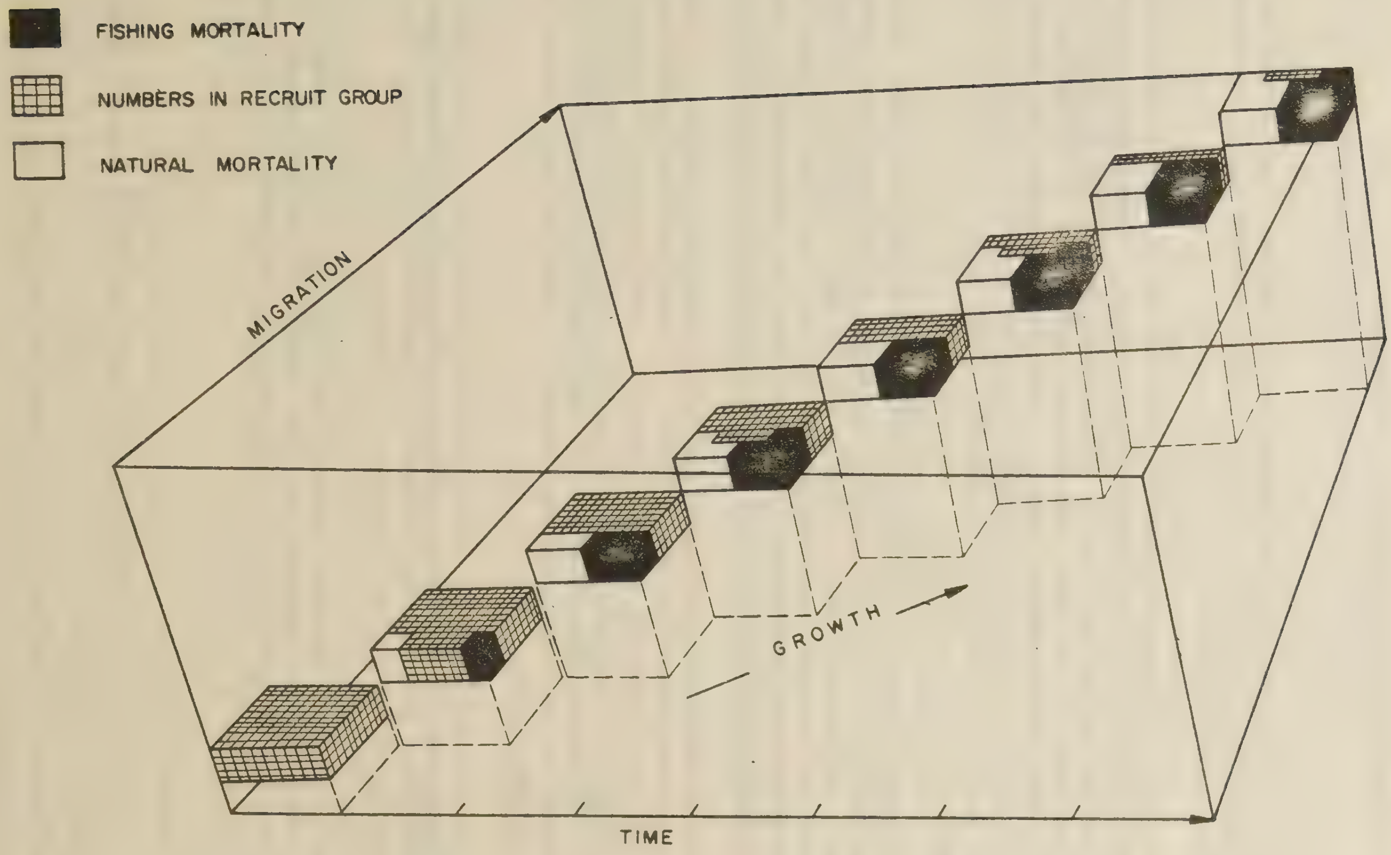
FISHING MORTALITY
NUMBERS IN RECRUIT GROUP
NATURAL MORTALITY
MIGRATION
GROWTH
TIME

Fig. 2 Simplified representation of the fate of a recruit group, MCL_n, after its entry into the Shark Bay fishery. At the end of each week the mean carapace length of the group increases by one unit and they migrate one unit. Fishing mortality (black) and natural mortality (white) are operating at the same rate. The number remaining at the end of each week is depicted by the grey shading. The co-ordinates of the model are given in Fig. 1.

weekly rate of exploitation is approximated by $(N_i - N_{i-1})/N_i$. The total number of prawns on the grounds at any particular week i (N^t_i) is given by

$$N^t_i = \sum_{j=o}^{x} \sum_{k=o}^{k} D_{ijk}$$

where k represents the number of blocks within the fishery.

3 DISCUSSION

Analytical aspects of the model require further development, and ultimately it is planned to programme estimation of the migration, growth amd mortality parameters as a single computer operation.

Two steps in the testing of these analytical aspects of the model will be used. The first is to simulate the model on the computer and, using iterative processes, estimate the most likely parameter values that produce results similar to those observed in the field. The second will be to make independent estimates of parameters and compare them with estimates obtained from the model. The best prospect of producing such independent estimates of growth, exploitation and migration is by tagging or marking. Estimates of numbers of juveniles leaving the nursery areas will be used for independent estimates of recruitment.

The relationship between catch per unit of effort (C/UE) and absolute density (D) is not simple. Cyclic changes in catchability associated with lunar and diurnal changes have already been postulated (Racek, 1959; Slack-Smith, 1969). Methods of making direct measurements of density are being explored so that these relationships can be investigated. Thus, catch and effort data can then be converted to actual density when exploitation and mortality rates and population size are being assessed.

The short life span of penaeids precludes any long term predictions of events based on biology or population dynamics within the fishery. There has been some success in associating population changes with the physico-chemical environment (St. Amant, Broome and Ford, 1966). However, the long-term prediction of these physico-chemical changes is notoriously difficult (Slack-Smith, 1969). It is considered, therefore, that the rather violent fluctuations in penaeid catch universally observed will remain largely unpredictable on a long-term basis.

If fishing intensity is sufficiently high to affect recruitment, then some form of short-term prediction of events is possible. However, Ingle (1961) states that it is most unlikely that fishing can ever be sufficiently intense to deplete spawners to the point of affecting recruitment, as prawn fecundity is extremely high.

Destruction of the biota and sediment balance by trawling in some areas (Slack-Smith, 1969) has been postulated as another possible cause of falling catch. However, rather than decreasing recruitment this would increase natural mortality or bring about changes in path or speed of migration.

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THE USE OF PREDATOR FOOD HABITS IN ESTIMATING RELATIVE ABUNDANCE OF THE OCEAN SHRIMP, *Pandalus jordani* RATHBUN

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Abstract

The food habits of fish were studied in conjunction with surveys of *Pandalus jordani* off northern California, to examine the predator-prey relationship between fish and ocean shrimp and to decide if a particular predator could be used to estimate relative abundance of ocean shrimp. After some study of the stomach contents of 16 species of fish, the Pacific hake, *Merluccius productus*, was chosen for detailed study.

Stomachs of 1,613 Pacific hake were examined between July 1964 and October 1966. The ocean shrimp year class composition in Pacific hake stomachs compared favorably with that estimated from sea surveys. Growth rates calculated for the youngest shrimp year class in the hake stomachs were similar to those calculated from market and sea survey samples. The average number of ocean shrimp in each year class per hake stomach was used to calculate annual mortality rates, which were quite consistent for the 1962, 1963 and 1964 year classes.

E/35

UTILISATION DES HABITUDES ALIMENTAIRES DES PREDATEURS POUR ESTIMER L'ABONDANCE RELATIVE DE LA CREVETTE *Pandalus jordani* RATHBUN

Résumé

On a examiné les habitudes alimentaires de certains poissons en les rapprochant d'études sur *Pandalus jordani* au large de la Californie du Nord, afin de voir, sur la base du rapport prédateur/proie existant entre poissons et cette crevette, si un certain prédateur pouvait servir à estimer l'abondance relative de *P. jordani*. Après analyse des contenus stomacaux de 16 espèces de poissons, c'est le merlu *Merluccius proproductus* qui a été choisi pour étude plus approfondie.

Les estomacs de 1 613 merlus *M. productus* ont été examinés entre juillet 1964 et octobre 1966. La composition par classe d'âge des crevettes *P. jordani* trouvées dans les estomacs de *M. productus* cadrait bien avec les estimations fournies par des enquêtes en mer. Les taux de croissance calculés pour la plus jeune classe d'âge de crevettes trouvées dans les estomacs de merlus étaient analogues à ceux qui avaient été calculés sur la base d'échantillons provenant des marchés ou récoltés en mer. On a utilisé le nombre moyen de crevettes de chaque classe d'âge par estomac de merlu pour calculer les taux annuels de mortalité, qui se sont révélés très cohérents pour les classes 1962, 1963 et 1964.

EL EMPLEO DE LOS HABITOS ALIMENTARIOS DE LOS PREDADORES PARA ESTIMAR LA ABUNDANCIA RELATIVA DEL CAMARON, *Pandalus jordani* RATHBUN

Extracto

Se estudiaron los hábitos alimentarios de peces simultáneamente con reconocimientos de *P. jordani* en aguas del norte de California, para examinar la relación predador-presa entre peces y camarones y poder decidir si un predador determinado podría emplearse para estimar la abundancia relativa del camarón. Después de examinar el contenido estomacal de 16 especies de peces, se seleccionó la merluza del Pacífico, *Merluccius productus* para realizar estudios detallados.

Entre julio de 1964 y octubre de 1966 se examinaron los estómagos de 1.613 merluzas del Pacífico. La composición por clases anuales del camarón en los estómagos de la merluza del Pacífico concordaba bastante bien con las estimaciones hechas a base de reconocimientos efectuados en el mar. Las tasas de crecimiento calculadas para la clase anual de camarón más joven encontrado en los estómagos de las merluzas eran análogas a las calculadas a partir de muestras obtenidas en los mercados y en el mar. Se empleó el número medio de camarones de cada clase anual por estómago de merluza para calcular las tasas de mortalidad anuales, que eran bastante constantes para las clases de 1962, 1963 y 1964.

1 INTRODUCTION

A series of sea surveys was undertaken in the spring of 1965 to investigate California's northern ocean shrimp population, which has supported a commercial fishery since 1958 (Dahlstrom 1961). The purpose of the surveys was to obtain reliable estimates of population size, year class composition and mortality rates for use in developing a yield equation. The surveys were conducted in a 500 km^2 area (Fig. 1) using a stratified random sampling design.

1.1 Predator food habit study

In conjunction with the sea surveys, we examined the stomach contents of larger fish, caught incidentally on the shrimp bed, to determine possible predator-prey relations. This study began in July 1964 when Pacific hake (*Merluccius productus*) were observed regurgitating large numbers of 1964 year class ocean shrimp (*Pandalus jordani*). We suspected that predator food habits might indicate the relative abundance of the incoming year class of shrimp and help us to follow their growth rates. Ocean shrimp do not become fully vulnerable to commercial nets until their second year of life, and even with a 1.27 cm stretch mesh liner in the cod end, significant numbers of younger shrimp escape.

1.2 Predators as biological samplers

The idea of using predators in population studies is not new. Thorson (1957) has suggested the use of predators to estimate benthic productivity. From stomach contents of Atlantic cod (*Gadus callarias*) Powles (1965) estimated the mortality of plaice (*Hippoglossoides platessoides*) due to Atlantic cod grazing. Gotshall, Smith and Holbert (1965) suggested that blue rockfish (*Sebastodes mystinus*) stomach contents may be used to indicate relative abundance of juvenile and larval crustaceans and fish.

2 METHODS

2.1 Collection and examination of stomachs

Stomachs were obtained from fish caught on the shrimp bed (Fig. 1) in various types of otter trawls, including those of commercial shrimp vessels (3.81 cm mesh), bottomfish trawlers (11.43 cm mesh), and California Department of Fish and Game research vessels. On the sea surveys, research vessels used a 12.50 m semi-balloon Gulf shrimp trawl with 2.54 cm stretch mesh and 1.27 cm stretch mesh liner in the cod end. Stomachs were removed from the fish soon after capture and preserved in 70 per cent isopropyl alcohol. When the stomachs were removed, organisms found in the mouths and throats of the fishes were discarded. Data collected from each fish included: species, total length, sex, date and location of capture.

Stomach contents were examined under a dissecting microscope. Identifiable organisms were measured, counted, and their volumetric displacement determined in a graduated cylinder.

2.2 Ocean shrimp age determination

Ocean shrimp are aged in California by a combination of criteria using carapace length frequencies. These include growth rate studies and age of sexual change. California studies indicate that all male ocean shrimp enter the transitional phase before they are two years old, and all transitionals become females before their third year of life (Dahlstrom, in press). Studies by Butler (1964) have shown this to be true also with British Columbia ocean shrimp.

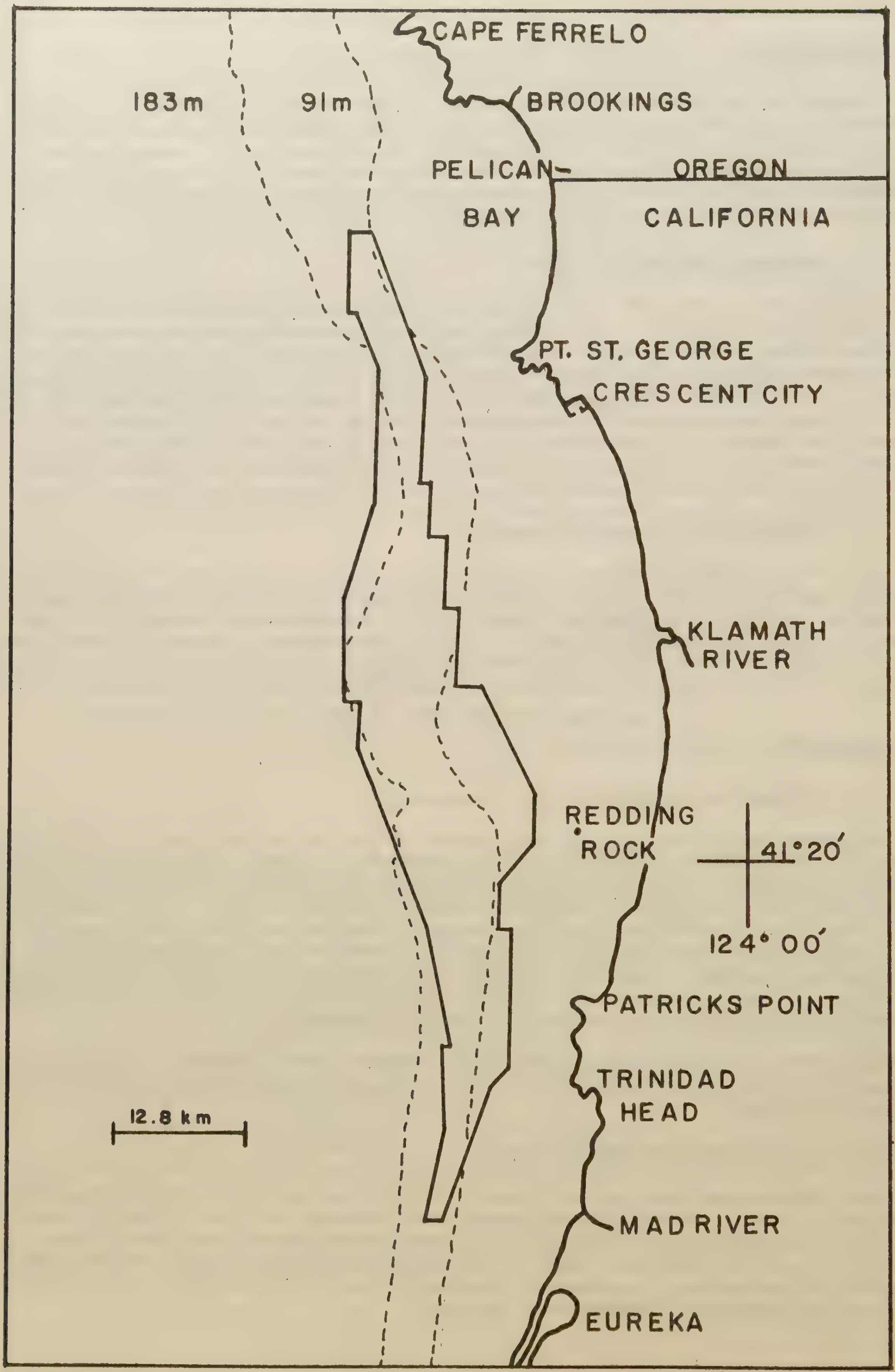

CAPE FERRELO
183m
91m
BROOKINGS
PELICAN
BAY
OREGON
CALIFORNIA
PT. ST. GEORGE
CRESCENT CITY
KLAMATH
RIVER
REDDING
ROCK
41°20′
124° 00′
PATRICKS POINT
TRINIDAD
HEAD
12.8 km
MAD RIVER
EUREKA

Fig. 1 Area in which the surveys were conducted.

One and two-year-old shrimps are separated at that size immediately following the last male measurement where the frequency distribution reaches the minimum. Two and three-year-old shrimps are divided at the minimum frequency immediately following the last transitional measure. For example, in August 1966 the 1965 year class of ocean shrimps captured off northern California had a size range of 14.4 to 18.6 mm, 1964 year class shrimp ranged in size from 18.8 to 22.6 mm and 1963 year class shrimp ranged from 22.8 to 24.2 mm carapace length.

2.3 Population estimates from sea survey

The stratified random sampling program used on our sea survey was designed by our biostatistical staff. A manuscript describing the method is in preparation (Abramson, pers. comm.) We are also in the process of preparing a paper describing the results of the sea surveys. The survey area (Fig. 1) was divided into 14 strata of unequal size. The first 10 strata made up the area of consistent commercial fishing success, based on catch data dating back to 1952. Strata 11 through 14 consisted of areas of limited commercial fishing success. Thirty-nine randomly selected trawls were assigned to the survey area (excluding known snag areas). If these were completed, an additional 39 trawls were attempted, and so on until the number of days allotted for the survey were used up. Ten of the 39 trawls were assigned to strata numbers 11 through 14, the number per stratum depending upon the area of the stratum. The remaining 29 trawls were assigned to the first 10 strata, the number per stratum again depending on the area.

The length of each trawl is 0.8 km, and the net opening averages 7.6 m; thus the area swept by the trawl equals 6131.6 m^2.

The shrimps from each trawl were placed in sampling boxes, each box containing 80 equal sized compartments. Two samples were selected from the boxes using random number lists. The shrimps in the samples were measured, sexed and weighed to determine the age composition and total weight of the catch. All of the catch data were processed by computer (Abramson, pers. comm.). The resulting mean catch per trawl for each stratum was expanded to an estimated total population for the stratum by multiplying it by the total number of possible trawls in the strata. The estimated population of each year class is equal to the sum of the estimates in the 14 strata.

2.4 Market sampling

Samples of ocean shrimp are obtained from northern California commercial landings through the season at Eureka and Crescent City, and as many of the landings as possible are sampled. The sample consists of filling a one liter container with shrimp from the catch. The sample may range from as few as 50 shrimps to over 150 shrimps, depending on the number of one-year-old shrimps in the sample. During the 1966 season (May to 7 August) a total of 15 boats made 363 landings. A total of 155 samples containing 17,474 shrimps were obtained from these landings.

3 RESULTS

3.1 July to September 1964 study

We examined 242 stomachs from 16 species of fish, collected from July to September, 1964. Stomach contents were analyzed in some detail but only results relating to ocean shrimp are included in the present paper. Ocean shrimps were found in stomachs from 8 species of fish. Pacific hake (Merluccius productus) and arrowtooth flounder (Atheresthes stomias) were selected for a one year intensive analysis of stomach contents. These two species were chosen because they were easy to obtain and a large proportion of their stomachs contained ocean shrimp; 97 of 164 hake stomachs, and 10 of 15 flounder stomachs.

Other species from which a large proportion of stomachs contained ocean shrimp were flat rockfish (Sebastodes rubrivinctus), sablefish (Anoplopoma fimbria), petrale sole (Eopsetta jordani), yellowtail rockfish (S. flavidus), greenstripe rockfish (S. elongatus), and stripetail rockfish (S. saxicola). These fish were not included in the 12-month study because large numbers of fish were difficult to obtain, or, in the case of the rockfish, because of the tendency for the expanding swim bladder to evert the stomach when brought to the surface from depths. It is unfortunate that flag rockfish could not be used, because the two stomachs of this species examined contained 170 juvenile (1964 year class) and adult ocean shrimp.

3.2 Arrowtooth flounder study

Arrowtooth flounder stomachs were collected monthly from September 1964 to October 1965, except in January 1965. We examined 425 stomachs during this period and found that 172 were empty. Juvenile shrimps (1964 and 1965 year classes) were present in 33 stomachs. Adult shrimps (1962, 1963 and 1964 year classes) were found in 102 stomachs, but were not present in those collected during November and December 1964 or February and March 1965. This is not surprising since the December 1964 and February 1965 stomachs were not from fish captured on the shrimp bed. The lack of shrimps in the November and March stomachs was probably due to the small sample. The stomachs from December collections were from 185 fathoms (340 m) west of Eureka, California, and the February samples were trawled west of Patricks Point in 380 fathoms (660 m). Crustaceans as a group were the dominant food of arrowtooth flounder during the study period.

3.3 Pacific hake study

A total of 527 Pacific hake stomachs was examined from July 1964 to September 1965 and 77 were empty. Adult shrimp (1961, 1962, 1963 and 1964 year classes) were found in 202 stomachs and juvenile shrimp (1964 and 1965 year classes) in 131 of the stomachs. Euphausiids were present in more stomachs than any other organism. Slender sole Lyopsetta exilis was the dominant food fish, appearing in 17 stomachs. These flatfish were also the fish most frequently taken in our survey trawls.

When we compared the number of ocean shrimp per arrowtooth flounder stomach and Pacific hake stomach, we found that Pacific hake not only contained more shrimp per stomach, but had preyed upon all of the year classes present in the shrimp population, including the outgoing 1961 year class which was not represented in the flounder stomachs. For these reasons Pacific hake were selected as our biological samplers and we discontinued collecting stomachs from flounder.

3.4 Pacific hake study, October 1965/66

Beginning in October 1965 the method of analysis of stomach contents was modified. Instead of preserving the stomachs, their contents were removed and examined at the time of collection, and organisms other than ocean shrimp were discarded. After October 1965, we examined 1,086 Pacific hake stomachs, of which 54 were empty.

3.4.1 Relative abundance of ocean shrimp year classes in Pacific hake stomachs

The 1964 year class was the most numerous age group found in hake stomachs from July 1964 to July 1966 (Table I). This year class provided the greatest portion of the catch of the commercial fishery during the 1965 and 1966 seasons. Our sea surveys indicated that the 1964 year class dominated the northern California ocean shrimp population until the spring of 1966 (Table II).

The 1965 year class was represented by fewer shrimp in both the hake stomachs and the fishery. Our sea surveys confirmed that this year class was not as numerous as the 1964 year class. Both Pacific hake stomachs and the sea survey indicated that

TABLE I

f 1961, 1962, 1963, 1964, 1965 and 1966 year class
shrimp per Pacific hake stomach collected off
ern California 1/, July 1964 2/ - October 1966

	2	Year Class 1963	1964	1965	1966	No. of stomachs 3/	No. of cean shrimp
		0.44	1.38			16	29
						75	236
						42	227
						73	597
						3	2
						69	59
						30	71
						43	21
			5	0.09		54	164
			9	0.78		27	76
Sept.			.25	0.08		12	22
Oct.	0.01	0.08	1.45	0.39		152	291
1966							
April		0.05	0.20	0.43		210	135
May		0.11	1.78	0.67		9	23
June		0.03	0.85	0.42	0.08	190	262
July			0.77	0.38	0.08	74	91
Aug.			0.10	0.18	0.46	150	111
Sept.			0.52	0.61	2.60	122	455
Oct.		0.08	0.75	1.58	5.84	125	1 020

1/ 107 September and all October 1966 stomachs collected off Brookings, Oregon
2/ December 1964 not included because hake were not captured on shrimp bed
3/ Does not include empty stomachs

TABLE II

Numbers of 1962, 1963, 1964, 1965 and 1966 year class shrimp in population surveyed off Northern California and Southern Oregon, October 1964 - October 1966

Survey Period	Area	Year Class (Millions)					
		1961	1962	1963	1964	1965	1966
6-12 Sept. 1964	Cape Ferralo to Redding Rock	6	51	86	1,038		
10 Mar.-23 Apr. 1965	Pelican Bay 1/ Mad River		14	76	797		
1 June-1 July 1965	" "		6	64	961		
27 Sept.-22 Oct. 1965	" "		6	59	536	76	
18 Mar.-27 Apr. 1966	" "			20	372	355	
15 Aug.-10 Sept. 1966 2/	" "			3	156	183	1,766

1/ See Fig. 1

2/ Includes estimate of population off Brookings, Oregon, made by Oregon Fish Commission the incoming 1966 year class was more abundant than the 1965 year class, but not as abundant as the 1964 year class (Tables I and II).

In comparing the percentage composition of the various year classes of shrimp in hake stomachs with our sea survey data and commercial catch samples (Table III), we find that year class compositions determined from stomach and sea surveys are quite similar, while hake stomach results differ from those obtained from commercial landings. This is what we would expect if the food intake of hake is a representative sample of the shrimp population. We assume that our sea surveys reliably measure the relative abundance of all but the incoming year class. In the autumn, the stomachs appear to yield a more accurate index of the abundance for the incoming year class than do our sea surveys.

3.4.2 Length frequencies of incoming year class Assuming Pacific hake are randomly feeding on ocean shrimp, the length composition of shrimp from stomachs should reflect the size composition of the population. To illustrate this relation, we can compare shrimp lengths of incoming year classes obtained from various sources, since there is no overlap with preceding year class lengths.

Comparative size data are available for the 1964, 1965 and 1966 incoming year classes (Fig. 2). The length frequency modes from the stomachs and commercial or sea survey samples are the same in each case except in August 1966. Generally, Pacific hake stomachs yielded a wider range of sizes and tended to include smaller shrimp than either the sea surveys or commercial fishery samples. From these comparisons it would seem that ocean shrimp growth rates could be followed by using hake as samplers.

3.4.3 Mortality rates Another method for comparing the effectiveness of Pacific hake as biological samplers is to examine mortality rates calculated from the numbers of shrimp in hake stomachs and sea survey data.

The following equation was used to calculate total mortality rates (Ricker, 1958).

$$it = -\log_e (N_t/N_o)$$

where:

t = the fraction of the year between the estimate of N_o and N_t

i = instantaneous rate of total mortality

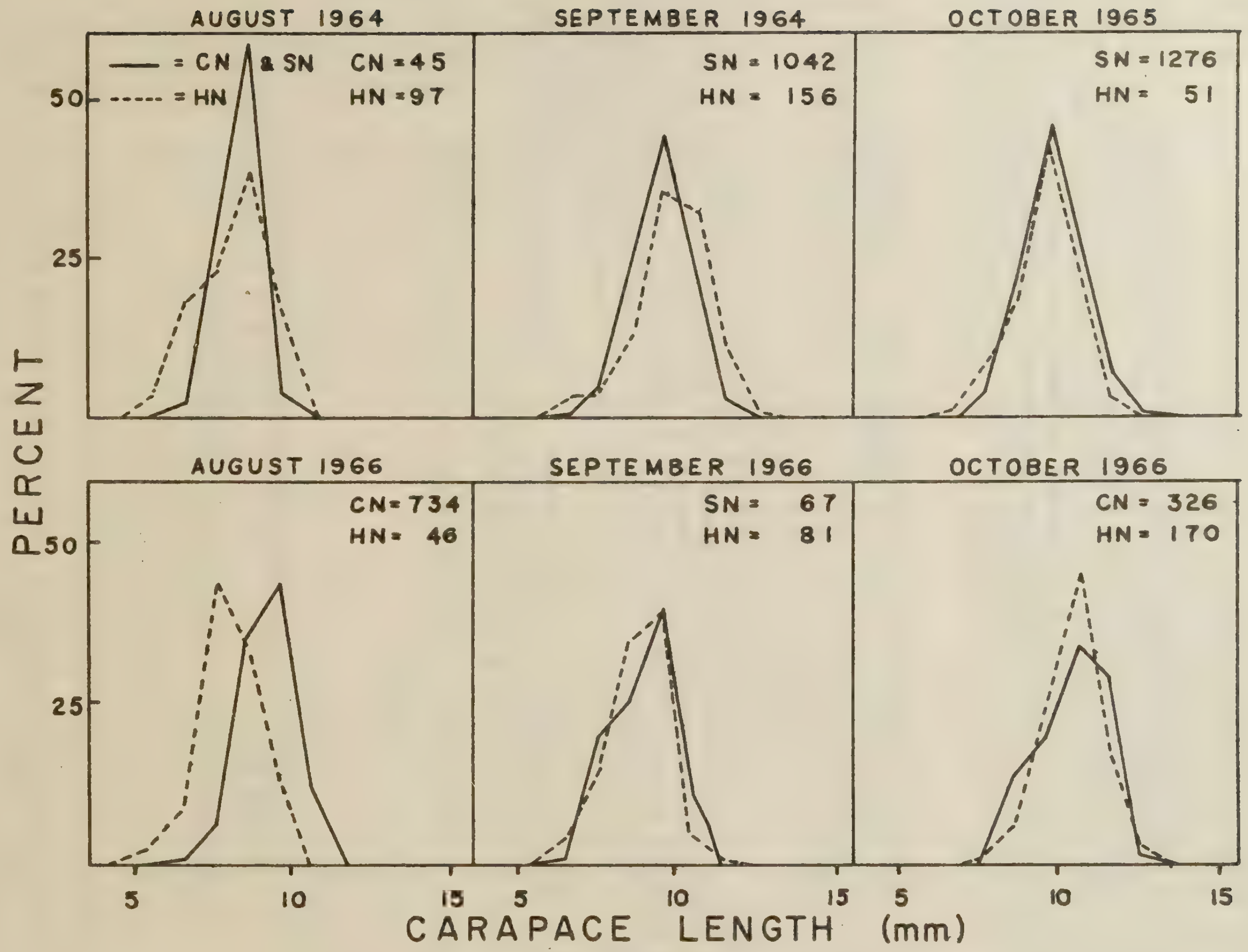
$\log_e$ = natural or naperian logarithms

N_t = index or numbers of a given year class at time t

N_o = index or numbers of a given year class at some time previous to t

Annual total mortality rates (a) were derived from Ricker's tables. Values of N for hake stomach data for autumn months were calculated by adding together the number of shrimp of a given year class for July through October and dividing by the total number of stomachs (excluding empty stomachs). The spring N value was based on the mean number of shrimp per stomach from April through July (Tables IV, V and VI). The sea survey estimates of N are the result of our stratified random sampling except for the September 1964 survey (Table II). This survey was conducted using random and non-random tows over a smaller sampling area. We believe, therefore, that the 1964 survey produced under-estimates of population size and of mortality rates.

The autumn 1966 population estimates include the population off Brookings, Oregon. These estimates are the result of an October sea survey conducted by the Oregon Fish



CN = NUMBER OF SHRIMP FROM COMMERCIAL SAMPLES
SN = NUMBER OF SHRIMP FROM SEA SURVEY SAMPLES
HN = NUMBER OF SHRIMP FROM HAKE STOMACHS

Fig. 2 Comparative size data for the 1964, 1965 and 1966 incoming year classes.

TABLE III

Comparison 1/ of percent composition (by numbers) of Northern California ocean shrimp year classes in Pacific hake stomachs with fishery (market) sampling and sea surveys of population, July 1964-October 1966

	Year Class					
	1961	1962	1963	1964	1965	1966
1964						
July						
Hake			24.1	75.9		
Fishery	2.1	47.4	50.5			
August						
Hake	0.8	14.4	39.0	45.8		
Fishery	2.1	43.1	54.8			
September						
Hake		1.3	5.3	93.4		
Sea survey	0.6	5.2	6.2	88.0		
1965						
April						
Hake		9.8	8.2	82.0		
Sea survey		3.4	10.8	85.8		
May						
Hake		5.6	5.6	88.7		
Fishery		11.3	27.5	61.2		
June						
Hake				100.0		
Fishery		2.9	26.5	70.6		
Sea survey		0.6	6.2	93.2		
July						
Hake			3.0	94.0	3.0	
Fishery		1.3	11.9	86.8		
October						
Hake		0.3	4.1	74.9	20.6	
Sea survey		1.1	8.7	78.7	11.6	

(continued)

TABLE III (continued)

	Year Class					
	1961	1962	1963	1964	1965	1966
1966						
April						
Hake			2.7	49.8	47.5	
Sea survey			0.7	31.8	67.4	
May						
Hake			4.3	69.6	26.1	
Fishery			5.8	79.5	14.7	
June						
Hake			2.3	61.4	30.2	6.1
Fishery			3.5	73.5	23.0	
July						
Hake				64.0	29.2	6.7
Fishery			3.1	71.7	25.2	
August						
Hake				13.5	24.3	62.2
Fishery			3.1	69.9	26.8	0.2
Sea survey			0.5	13.8	22.1	63.6
September 2/						
Hake				14.2	16.2	69.5
Fishery			0.2	55.7	39.1	5.0
October						
Hake			0.1	9.2	19.3	71.4
Fishery			0.4	51.0	34.8	13.8
Sea survey 3/				4.1	4.3	91.6

1/ Comparative fishery or sea survey data not available during October 1964 or August and September 1965

2/ Pacific hake and commercial fishery data from Brookings, Oregon

3/ Conducted by Oregon Fish Commission (Jack Robinson pers. comm.)

TABLE IV

Comparison of instantaneous mortality rates
and annual mortality rates of 1962 year class
Northern California ocean shrimp calculated from
Pacific hake stomachs 1/ and sea surveys 2/
1964 - 1965

	N_t	N_o	it	t	i	a
Autumn 1964 to Spring 1965						
Hake	.05	.19	1.34	0.750	1.78	0.83
Sea survey 3/	14	51	1.29	0.583	2.21	0.89
Sea survey 4/	6	51	2.14	0.750	2.85	0.94
Autumn 1964 to Autumn 1965						
Hake	.01	.19	2.94	1.000	2.94	0.95
Sea survey	8	51	1.85	1.083	1.70	0.82
Spring 1965 to Autumn 1965						
Hake	.01	.05	1.609	0.333	4.83	1.00
Sea survey 3/	8	14	0.560	0.5000	1.12	0.67
Sea survey 4/	8	6	--	--	--	--

1/ Spring value calculated from total shrimp divided by total stomachs collected from April through July, Autumn value, equals total shrimp divided by total stomachs collected from July through October

2/ Survey dates: September 1964, April 1965, June 1965, October 1965, April 1966, and August 1966

3/ Survey, April 1965

4/ Survey, June 1965

TABLE V

Comparison of instantaneous mortality rates and annual mortality rates of 1963 year class Northern California ocean shrimp calculated from Pacific hake stomachs [1] and sea surveys [2] 1964 - 1966

	N_t	N_o	it	t	i	a
Autumn 1964 to Spring 1965						
Hake	0.07	0.55	1.976	0.750	2.63	0.93
Sea survey [3]	76	86	.124	0.583	0.21	0.20
Sea survey [4]	64	86	.295	0.750	0.39	0.32
Autumn 1964 to Autumn 1965						
Hake	0.14	0.55	1.283	1.000	1.28	0.72
Sea survey	59	86	.377	1.083	0.35	0.30
Spring 1965 to Autumn 1965						
Hake	0.14	.07				
Sea survey [3]	59	76	.253	0.500	0.51	0.40
Sea survey [4]	59	64	.081	0.333	0.24	0.21
Spring 1965 to Spring 1966						
Hake	0.02	0.07	1.253	1.000	1.25	0.71
Sea survey [3]	20	76	1.335	1.000	1.34	0.74
Sea survey [4]	20	64	1.163	0.833	1.40	0.75
Autumn 1965 to Spring 1966						
Hake	0.02	0.14	1.946	0.750	2.59	0.92
Sea survey	20	59	1.082	0.500	2.16	0.88
Autumn 1965 to Autumn 1966						
Hake	0.002	0.14	4.248	1.000	4.25	0.99
Sea survey	3	59	2.979	0.833	3.58	0.97
Spring 1966 to Autumn 1966						
Hake	0.002	0.02	2.302	0.333	6.91	1.00
Sea survey	3	20	1.897	0.333	5.69	1.00

---

[1] Spring value calculated from total shrimp divided by total stomachs collected from April through July, Autumn value, equals total shrimp divided by total stomachs collected from July through October

[2] Survey dates: September 1964, April 1965, June 1965, October 1965, April 1966, and August 1966

[3] Survey, April 1965

[4] Survey, June 1965

Commission that used a sampling method similar to ours (Robinson, pers. comm.). The population off Brookings consisted of 1,430 million 1966 year class shrimp, 67 million 1965 year class shrimp, and 64 million 1964 year class shrimp. They were included because we have reason to believe that these shrimp are part of the northern California population that moved with a subsurface current into Oregon waters.

The 1965 year class was not included in the comparisons because the autumn 1965 mean N was smaller than the spring and autumn 1965 mean N values.

3.4.3.1 Year class mortality The a values from the sea surveys and stomachs for the 1962 year class are quite similar (Table IV). The a value from hake stomachs increased with time until it reached the maximum value of 1.00 between the spring and autumn of 1965. This is expected for this age class, as it apparently suffers total mortality during the winter and spring of the fourth year of life (Dahlstrom, in press; Butler, 1964).

Annual mortality rates for the 1963 and 1964 year class from the shrimp per stomach and sea survey data did not agree as closely as those calculated for the 1962 year class (Tables V and VI). Best agreement was from the spring of 1965 to the spring of 1966 and autumn of 1965 to autumn of 1966. The greatest discrepancy in estimates occurred from the autumn of 1964 to spring 1965.

Generally the annual mortality rates derived from Pacific hake stomachs were higher than those calculated from the sea surveys. The small time intervals (t) for the shrimp per stomach annual mortality rate generally yielded lower estimates of a. Total annual mortality (a) could not be calculated for the 1963 or 1964 year class from the spring 1965 to autumn 1965 N values.

The most significant a values in terms of consistency were those derived from the hake stomachs from autumn 1964 to spring 1965, and autumn 1965 to spring 1966. The 1963 year class a values for these periods were 0.93 and 0.92 respectively, and the 1964 year class estimates were 0.78 and 0.78. Since this mortality took place when there was no fishery, the annual mortality rate (a) is equivalent to the annual natural mortality rate (n) (Ricker, 1958).

4 DISCUSSION

The concept of predator sampling involves two basic assumptions:

(i) That the predator randomly feeds on the prey species throughout its range and does not select a particular size or age

(ii) That all sizes or ages of the species under study are equally vulnerable to the predator

We must consider several possible sources of error in using predators as biological samplers. One of the first questions that arose in our study was: are the Pacific hake or other predators feeding on the shrimps that are in the net? We have no doubt that a few shrimps find their way into the mouths and throats, or even as far as the stomach. However, if all or most of the shrimps found in the stomachs were picked up in the net, then hake collected with the commercial bottomfish trawls (11.43 cm mesh) would not contain nearly as many shrimps as those caught with the shrimp trawls (3.81 cm mesh). The highest number of shrimp per stomach occurred during October 1964 when all the hake sampled were obtained from commercial bottomfish trawlers (Table I). Also, there was a difference between the age composition of shrimps in hake stomachs and the age composition of the commercial shrimp fishery samples, and close agreement between age composition of shrimps in hake stomachs and those in sea survey samples (Table III). This would be expected if Pacific hake feed on shrimps outside the net.

TABLE VI

Comparison of instantaneous mortality rates and annual mortality rates of 1964 year class Northern California ocean shrimp calculated from Pacific hake stomachs 1/ and sea survey 2/

	N_t	N_o	it	t	i	a
Autumn 1964 to Spring 1965						
Hake	1.47	4.53	1.125	0.750	1.50	.78
Sea survey 3/	797	1038	0.266	0.583	0.46	.37
Sea survey 4/	961	1038	0.079	0.750	0.10	.10
Autumn 1964 to Autumn 1965						
Hake	1.76	4.53	.945	1.000	0.94	.61
Sea survey	536	1038	0.663	1.083	0.61	.46
Spring 1965 to Autumn 1965						
Hake	1.76	1.47				
Sea survey 3/	536	797	0.397	0.500	0.79	.55
Sea survey 4/	536	961	0.584	0.333	1.75	.83
Spring 1965 to Spring 1966						
Hake	0.57	1.47	0.947	1.000	0.95	.61
Sea survey 3/	372	797	0.762	1.000	0.76	.53
Sea survey 4/	372	961	0.949	0.833	1.14	.68
Autumn 1965 to Spring 1966						
Hake	0.57	1.76	1.127	0.750	1.50	.78
Sea survey	372	536	.365	0.500	0.73	.52
Autumn 1965 to Autumn 1966						
Hake	0.49	1.76	1.279	1.000	1.28	.72
Sea survey	156 5/	536	1.234	0.833	1.48	.77
Spring 1966 to Autumn 1966						
Hake	0.49	0.57	0.151	0.333	0.45	.36
Sea survey	156	372	.869	0.333	2.61	.93

1/ Spring value calculated from total shrimp divided by total stomachs collected from April through July. Autumn value, equals total shrimp divided by total stomachs collected from July through October

2/ Survey dates: September 1964, April 1965, June 1965, October 1965, April 1966, and August 1966

3/ Survey, April 1965

4/ Survey, June 1965

5/ Includes population off Brookings, Oregon

TABLE VII

Comparison of number of ocean shrimp found in stomachs
from various sizes of Pacific hake, July 1964–October 1966

	Total Length Groups (cm)							
	10–19	20–29	30–39	40–49	50–59	60–69	70–79	80–89
July-October 1964								
Number of stomachs 1/	4	11	6	62	67	52	3	0
Number without shrimp	4	10	0	14	12	17	0	0
Number of shrimp	0	1	12	113	527	415	13	0
Shrimp per stomach	0.00	0.09	2.00	1.82	7.86	7.98	4.33	0.00
March-October 1965								
Number of stomachs 1/		12	10	186	152	38	13	0
Number without shrimp		8	7	91	65	13	4	0
Number of shrimp		4	4	235	299	122	38	0
Shrimp per stomach		.33	.40	1.26	1.97	3.21	2.92	0.00
April-October 1966								
Number of stomachs 1/		12	35	481	238	92	8	1
Number without shrimp		12	25	234	95	29	3	0
Number of shrimp		0	15	521	696	734	60	11
Shrimp per stomach		0	.43	1.08	2.92	7.98	7.50	11.00

1/ Does not include empty stomachs

The small samples of hake stomachs during months when Pacific hake were scarce did not contain shrimp of all year classes in the fishery (Table I). One method of increasing the number of shrimp per stomach in our samples would be to consider only the larger hake, but a casual analysis of the size composition of shrimp found in stomachs from various sizes of hake suggests that larger hake tend to feed more on the smaller shrimp. Pacific hake 20.0 to 49.9 cm TL were compared with hake 50.0 to 79.9 cm TL; 65 percent of the shrimp in the stomachs from the smaller size group of hake were juveniles, as compared with 87 percent in the stomachs from the larger hake. Pacific hake 50 cm or longer in total length had from two to three times as many shrimps per stomach as the smaller hake (Table VII).

From the sea surveys, we know ocean shrimp year classes are not randomly distributed over the bed, therefore an attempt was made to obtain hake from throughout the shrimp bed. Nevertheless, some of the wide variation in our shrimp per stomach data may be attributed to this bias.

The relative abundance of Pacific hake in the shrimp area fluctuates widely during the year. They are usually absent from late November through March, and start appearing in the nets during April with the largest catches occurring during July, August and September. Unfortunately, from the data collected we cannot evaluate the effect of changes in hake abundance on hake predation of shrimp. It is interesting to note, however, that the highest shrimp per stomach values occurred during autumn, when the frequency of hake in survey tows was highest (Table I).

The reason for what appears to be an underestimate of the 1965 year class in hake stomachs in the autumn of 1965 and spring of 1966 remains a mystery, although we suspect that the smallness of the hake samples and bias from catch locations are probably both involved.

The entire concept of predator sampling requires further study. Future plans for research on the hake/shrimp relationship include designing a statistically valid sampling program, and further analysis of data to determine the best method for estimating various mortality rates.

Eventually it may be possible to discontinue our costly sea surveys, and derive annual yield estimates from predator stomach data and commercial fishing trends. We feel the concept of predator sampling has potential as a fisheries management tool. It remains for fishery biologists to develop the method.

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RECHERCHES SUR LE CYCLE BIOLOGIQUE DE LA CREVETTE *Penaeus duorarum* BURKENROAD 1939 AU DAHOMEY

par

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Résumé

Cette étude constitue une première recherche sur le cycle de la crevette *Penaeus duorarum* Burkenroad, en Afrique Equatoriale (Dahomey); elle a eu lieu d'octobre 1962 à avril 1964.

Ce sont les post-larves qui migrent de la mer vers les eaux saumâtres lagunaires. La relation entre la salinité et la densité de quatre populations ainsi que la croissance de ces populations sont étudiées mensuellement, ce qui entraîne l'examen de 10 000 *P. duorarum*. Les jeunes crevettes ne peuvent vivre en eau douce; elles supportent des salinités faibles de 0,5‰ mais ne se développent normalement qu'à des salinités de 5 à 34‰. L'alimentation est principalement d'origine animale (petits poissons, crustacés, polychètes).

Après quelques mois de vie en eau saumâtre, les crevettes se dirigent vers la mer et sont principalement pêchées sur les fonds vaseux de 40 à 55 m.

Aux divers stades (post-larves, jeunes crevettes, crevettes adultes), les crevettes *Penaeus duorarum* du Dahomey sont un peu plus grandes que celles de la Floride.

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RESEARCH ON THE BIOLOGICAL CYCLE OF Penaeus duorarum BURKENROAD 1939 IN DAHOMEY

Abstract

This paper constitutes initial research on the life cycle of Penaeus duorarum Burkenroad, in Equatorial Africa (Dahomey), lasting from October 1962 to April 1964.

The shrimps migrate at the post-larval stage from the sea in the direction of the brackish waters of the coastal lagoons. The relationships between salinity and the density of four populations and also the growth of these populations were examined monthly, some 10,000 specimens being involved. The young shrimps cannot survive in fresh water. They can withstand salinities as low as 0.5 °/oo but only develop normally in salinities ranging from 5 to 34 °/oo. Their food is chiefly of animal origin (small fish, crustaceans, and polychaetes).

After a few months in brackish water, the shrimps migrate seawards and are fished chiefly over muddy bottoms at depths of 40 to 55 m.

At the various stages (post-larval, juvenile, adult) the Penaeus duorarum of Dahomey are slightly larger in size than the Florida Penaeus at similar stages.

INVESTIGACIONES SOBRE EL CICLO BIOLOGICO DEL CAMARON Penaeus duorarum, BURKENROAD 1939 EN DAHOMEY

Extracto

Este estudio constituye la primera investigación sobre el ciclo del camarón Penaeus duorarum Burkenroad, en Africa Ecuatorial (Dahomey); esta investigación se realizó desde octubre de 1962 hasta abril de 1964.

Las postlarvas emigran desde el mar hacia las aguas salobres de las lagunas. Se estudia mensualmente la relación que existe entre la salinidad y la densidad de cuatro poblaciones, así como su crecimiento, lo que supone el examen de 10.000 P. duorarum. Los camarones jóvenes no pueden vivir en agua dulce; soportan salinidades bajas de 0,5‰ pero sólo se crían normalmente con grados de salinidad de 5 a 34‰. La alimentación es generalmente de origen animal (pequeños peces, crustáceos, poliquetos).

Después de pasar algunos meses en aguas salobres, los camarones salen al mar; aquí se les pesca, principalmente en fondos cenagosos de 40 a 55 metros.

En las diversas fases (postlarvas, camarones jóvenes, camarones adultos), camarón Penaeus duorarum, de Dahomey, es algo más grande que los de Florida.

1 INTRODUCTION

Le Décapode Macroure Natantia, Penaeus duorarum Burkenroad 1939, est répandu à la fois sur les côtes atlantiques de l'Amérique et de l'Afrique. C'est Burkenroad (1939) qui constata que l'espèce américaine, P. brasiliensis Latreille, correspondait en fait à trois espèces bien définies : P. brasiliensis Latreille, P. aztecus Ives et P. duorarum Burkenroad. Seule l'espèce P. duorarum existe sur la côte occidentale africaine. Il n'y a pas plus de différences entre P. duorarum d'Afrique et d'Amérique qu'entre les divers types de cette même espèce en Amérique (Holthuis, communication personnelle).

Sur la côte africaine, l'aire d'extension connue de P. duorarum est située entre la Mauritanie (Cap Blanc) et l'Angola (Luanda), c'est-à-dire entre le 21° de latitude nord et le 8° de latitude sud (Holthuis, 1952).

Dans ces mêmes eaux africaines, il existe également une autre espèce du même genre, Penaeus kerathurus Forskal 1775, mais celle-ci est absente de la côte atlantique américaine. Cette espèce est plus connue sous les noms de P. camarote Risso et de P. trisulcatus Leach; en Atlantique, elle s'étend du sud de l'Angleterre à l'Angola et est également commune en Méditerranée (Holthuis, 1952).

Il est facile de différencier ces deux espèces sur les côtes africaines par 4 caractères. Chez P. duorarum, le sixième somite abdominal montre, de chaque côté de la carène dorsale de ce somite, un sillon très net; il n'y a aucune trace de sillon chez P. kerathurus. D'autre part, P. duorarum est caractérisé par les sillons qui bordent latéralement la carène dorsale céphalothoracique sans atteindre l'extrémité postérieure de celle-ci; ces sillons atteignent nettement cette extrémité postérieure chez P. kerathurus et sont plus profondément creusés que chez P. duorarum. De plus, P. kerathurus porte des épines sur les coxae des trois premières paires de péréiopodes, ce qui n'est pas le cas chez P. duorarum. Enfin, l'abdomen des exemplaires de taille moyenne ou grande de P. kerathurus est zébré (bandes brunâtres alternant avec des bandes plus claires), alors que P. duorarum a un aspect uniforme.

Dans les eaux côtières dahoméennes, il existe également un autre Penaeidé très abondant, Parapenaeopsis atlantica. Cette espèce ne possède pas de sillon sur les côtés de la carène dorsale céphalothoracique; elle n'est connue que le long de la côte d'Afrique occidentale, entre le Ghana et l'Angola.

La présente étude est limitée à l'espèce Penaeus duorarum; elle correspond à des recherches effectuées dans la région de Cotonou (Dahomey) et en particulier dans une lagune saumâtre (lac Nokoué) (Fig. 1) d'octobre 1962 à mai 1964 (Hoestlandt, 1963, 1964, 1967) 1/. Dans ce lac, P. kerathurus jeune n'est que très rarement capturé; nous n'y avons jamais pêché de P. atlantica.

En Amérique, P. duorarum se reproduit en mer, les jeunes larves remontent dans les estuaires ou en lagune; c'est en milieu saumâtre que se poursuit la croissance juvénile, et c'est en mer que les crevettes deviennent adultes.

Il n'existe, à notre connaissance, qu'une seule étude antérieure sur P. duorarum au Dahomey; il s'agit d'une note de 1908 (Lefebvre, 1908) qui souligne l'importance économique de cette crevette dans le lac Ahémé (Fig. 6) à une époque où P. duorarum

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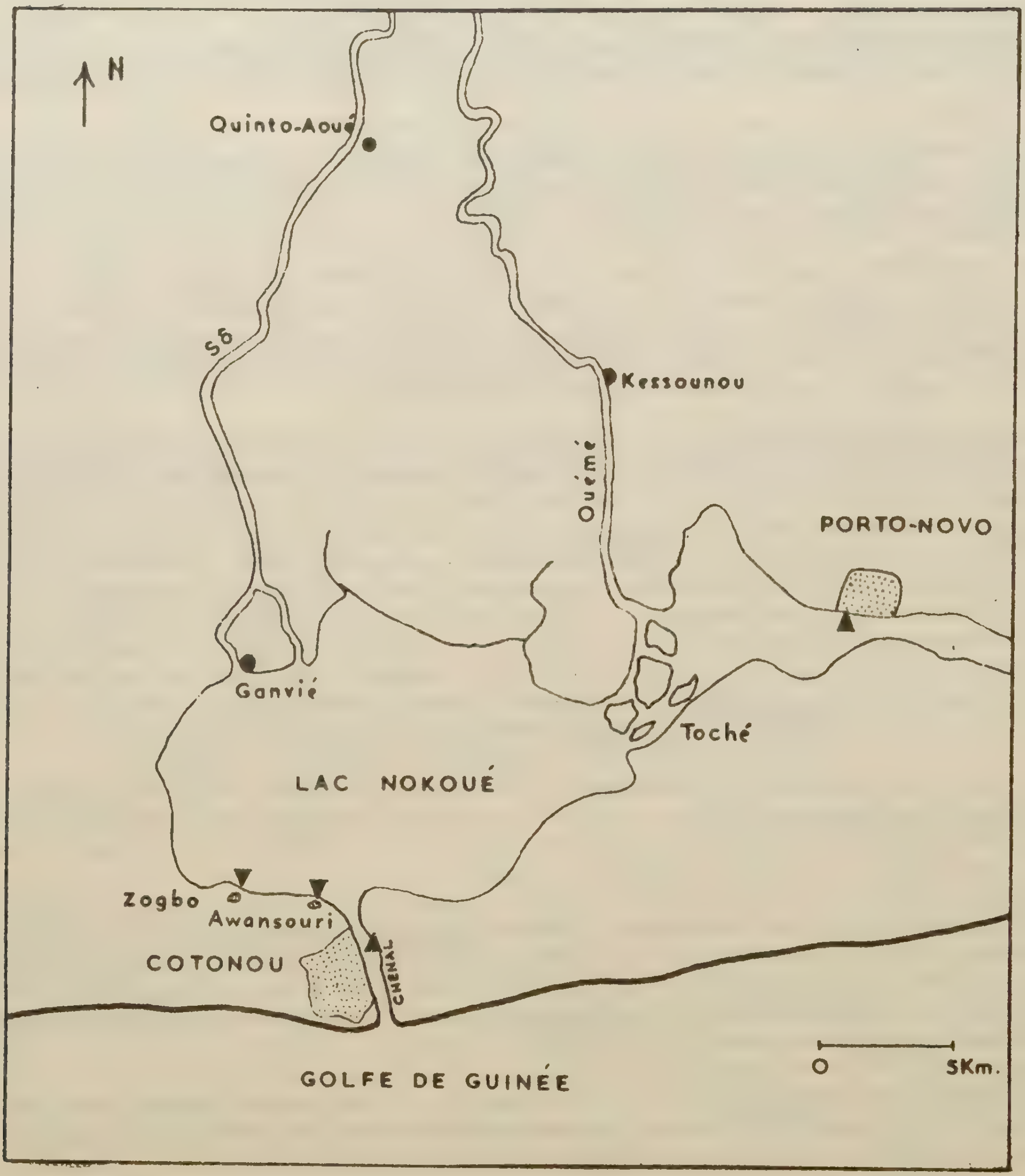
N
Quinto-Aoué
Sô
Kessounou
Ouémé
PORTO-NOVO
Ganvié
Toché
LAC NOKOUÉ
Zogbo
Awansouri
COTONOU
CHENAL
GOLFE DE GUINÉE
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5Km.

Fig. 1 Carte hydrographique de la Région du Lac Nokoué. Les triangles noirs indiquent les quatre stations de pêche de *P. duorarum*.

était peu connue dans le lac Nokoué. Il faut également indiquer une étude récente (Monod, 1967) sur l'importance des diverses crevettes le long de la côte occidentale d'Afrique.

2 DONNEES HYDROGRAPHIQUES ET CLIMATIQUES

Au début de cette étude, il est intéressant d'indiquer sommairement les caractéristiques de l'Hydrographie et de la Climatologie du Dahomey; ceci permet de comprendre les variations de salinité de la région lagunaire car la Biologie de P. duorarum est en relation avec ces variations.

2.1 Eaux intérieures

2.1.1 Hydrographie. Une grande partie des eaux de ruissellement du Dahomey descend vers la mer sur de vastes pénéplaines granito-gneissiques ou sédimentaires. Ces eaux se concentrent dans les trois principaux fleuves, le Mono, le Couffo et l' Ouémé. Le dernier de ces fleuves nous intéresse plus spécialement car il aboutit dans la lagune de Porto-Novo et dans le lac Nokoué par le Toché; de plus, ces deux lagunes sont reliées entre elles par de nombreux bras et chenaux. Il faut ajouter qu'un fleuve beaucoup moins important, la Sô, se jette également dans le lac Nokoué (Fig.1).

Le Bas Ouémé coule sur des alluvions récentes qui constituent une zone deltaïque de 75 km de longueur et de 10 à 15 km de largeur. De nombreux bras relient l'Ouémé à son affluent, le Zou, ainsi qu'avec la Sô. Dans cette zone deltaïque, la pente est très faible et la partie inférieure de cette zone est largement inondée en période de crue.

2.1.2 Importance des pluies. Les années correspondant à cette étude (1962-1964) sont des années pluvieuses; notre description climatologique (ainsi que l'étude biologique correspondante) ne concerneront donc pas le cas des années dites "sèches".

Dans le Haut Dahomey, le régime climatique est continental de type soudanien avec une saison sèche de novembre à mars et une saison pluvieuse d'avril à novembre.

Dans le Moyen Dahomey, le régime est transitoire avec une diminution des précipitations en août.

Dans le Bas Dahomey, le régime comporte nettement deux saisons sèches (novembre à fin mars et août) ainsi que deux saisons pluvieuses (avril à juillet et septembre à octobre).

Le régime hydrologique de la lagune de Porto-Novo et du lac Nokoué est sous la dépendance de la première saison des pluies du Bas-Dahomey (avril à juillet) et surtout de la crue de l'Ouémé provoquée par les pluies du Haut Dahomey et du Moyen Dahomey. La crue de ces deux lagunes a lieu de juillet à fin novembre, avec un maximum généralement en septembre. C'est en mars et en avril que le débit de l'Ouémé est minimum.

Le lac Nokoué est peu profond (1 m par basses eaux), mais en période de crue, la hauteur d'eau du lac peut atteindre 2 m; dans ce cas, le courant de marée n'existe plus dans le chenal de Cotonou (Fig.1).

2.1.3 Salinité.

- Lac Nokoué. En période de forte crue, de juillet ou août au début de novembre, les eaux du lac Nokoué sont douces et descendent vers la mer. Lors de la décrue de novembre, la marée amène de l'eau salée dans le chenal et la salinité augmente progressivement dans la lagune pour atteindre un maximum en février ou mars (salinité de 32 à 34‰). L'action des pluies est ressentie dès les mois d'avril ou mai et la salinité de la lagune diminue assez rapidement.

- Lagune de Porto-Novo. Comme cette lagune est plus éloignée de la mer que le lac Nokoué, la salinité apparaîtra plus tardivement et n'atteindra pas de taux élevé. Cette lagune demeure douce jusqu'en janvier et la salinité maximum correspond au mois d'avril; elle ne dépasse pas 17‰.

- Ouémé et Sô. En mars et en avril, l'eau saumâtre remonte le cours inférieur de ces fleuves dans le Bas Dahomey jusqu'à 30 km en amont de la lagune de Porto-Novo pour l'Ouémé (Kessounou) et du lac Nokoué pour la Sô (Quinto-Aoué) (Fig.1).

2.1.4 Température. Les lagunes côtières du Bas Dahomey ont une température équatoriale qui ne subit que très peu de variations au cours de l'année.

Dans le lac Nokoué, les températures de l'eau ont été régulièrement enregistrées. Le maximum de température se situe en avril (30,3°C) et le minimum en août (27,2°C); la différence des températures au cours de l'année ne dépasse donc pas 3°C. Ces variations de températures annuelles sont trop faibles pour influencer la biologie des crevettes, alors qu'aux Etats-Unis elles jouent peut-être un certain rôle (Chin, 1961).

2.2 Eaux marines du plateau continental

Des recherches récentes (Crosnier et Berrit, 1966) nous apportent les éléments nécessaires à notre étude. La pente du fond marin côtier est assez faible jusqu'à 80 m pour devenir forte ensuite. Les fonds sont sableux jusqu'à 15 m, ils sont sablo-vaseux de 15 à 40 m, vaseux de 40 à 55 m et rocheux coralliens de 55 à 80 m.

Il existe une stratification des eaux marines côtières du Dahomey avec variations saisonnières liées au régime austral d'une période chaude centrée en février et d'une période froide centrée en août. On peut cependant distinguer nettement trois couches d'eau, malgré les modifications saisonnières.

Il y a d'abord une couche d'eaux chaudes dont la profondeur atteint de 20 à 30 m. La salinité varie de 32‰ à 35‰, mais elle peut descendre parfois à 20‰ aux abords de la côte. Les changements de salinité sont liés aux apports des eaux douces en période de pluies ou aux remontées des eaux salées profondes ("upwellings"). La température de ces eaux s'échelonne entre 25 et 29°C.

Il y a ensuite une couche de discontinuité ou couche de la thermocline qui a une épaisseur de 15 à 20 m et est localisée par conséquent entre 30 et 50 m. La salinité de cette couche varie peu (35,6 à 35,9‰) et la température est de l'ordre de 25°C.

Il y a enfin une couche profonde froide, au-dessous de 50 m. Dans cette couche, la salinité décroit de 0,004‰ par mètre et la température diminue de 0,03°C par mètre. A la profondeur de 80 m la salinité est de 35,7‰ et la température de 17°C.

3 STADES POST-LARVAIRES

Les stades larvaires et post-larvaires des Penaeides sont aisément caractérisés grâce aux recherches de Gurney (1942); il est très facile d'identifier P. duorarum grâce aux travaux de Williams (1959) et surtout de Dobkin (1961).

3.1 Technique

Les larves et les post-larves sont planctoniques, c'est pourquoi nous les recherchons avec des filets planctoniques de mailles différentes afin de capturer, soit les stades nauplius et protozoé, soit les stades mysis et post-larvaires.

Des pêches sont réalisées en mer lors d'une sortie à bord d'un chalutier, d'autres sont effectuées régulièrement dans le chenal ainsi que dans le lac Nokoué et à Porto-Novo (Fig. 1)

La longueur des crevettes est toujours exprimée en longueur du céphalothorax, mesurée entre le creux orbitaire droit et l'extrémité distale médiane du céphalothorax.

3.2 Résultats

Les stades protozoé ou mysis ne sont trouvés ni en mer ni en lagune. Aux Etats-Unis, ces stades ne sont que rarement capturés, et ceci toujours en mer (Idyll, 1964).

Les jeunes stades post-larvaires sont capturés dans le lac Nokoué. Le premier stade post-larvaire, qui succède au troisième stade mysis, est reconnaissable par la présence d'une seule épine dorsale sur le rostre; ce stade n'a pas été capturé. Le stade post-larvaire le plus jeune, pris dans la lagune, possède 4 épines rostrales : ce stade a été pris en onze exemplaires à l'amont du chenal (Fig.1), en face d'Awansouri et même en face de Zogbo (un seul exemplaire en cette dernière station). Aux Etats-Unis, en Floride, c'est le même stade à 4 épines qui est le plus jeune stade pris en estuaire (Tabb, Dubrow and Jones, 1962).

La longueur de ce stade, exprimée en longueur du céphalothorax et mesurée au microscope, est en moyenne de 1,88 mm, ce qui correspond à une longueur totale de 7,5 à 8 mm. Signalons que ce stade ne mesure que 1,7 mm (longueur du céphalothorax) en Floride. Les post-larves du Dahomey sont donc légèrement plus grandes que celles de la Floride. Nous retrouverons ce caractère de dimensions plus grandes au cours de la croissance des P. duorarum du Dahomey.

Lebour (1959) donne le dessin d'une post-larve de P. duorarum, capturée en mer à hauteur du sud du Cameroun (2° 55'N. 9° 21'E.) le 28 novembre 1946, (2,5 mm de longueur totale de la carapace). Le dessin montre que cet exemplaire ne possède que 4 épines rostrales mais qu'il est déjà porteur de pléopodes biramés. Les exemplaires similaires que nous avons capturés au Dahomey ne comportent que des pléopodes uniramés Idyll (1964) reprenant l'étude de Lebour (1959), suggère qu'il y a peut-être une espèce ou une sous-espèce ouest-africaine différente de celle du sud de la Floride. Il n'y a pas lieu de retenir cette hypothèse mais plutôt d'estimer que la post-larve dessinée par Lebour (1959) était un spécimen exceptionnel anormal.

Le stade post-larvaire suivant comporte 5 épines rostrales; il n'est pas capturé dans le chenal, mais seulement à Awansouri et à Zogbo (3 exemplaires); il mesure 2,1 mm de longueur céphalothoracique. Les stades à 6 et 7 épines rostrales ne sont recueillis qu'à Zogbo (3 exemplaires).

Aucun stade post-larvaire n'a été pris à Porto-Novo.

Ces divers stades post-larvaires sont recueillis au Dahomey dès le mois de février. En Caroline, ils ne sont recueillis qu'à partir de mai; en Floride, on les prend dès le mois de mars; il n'est donc pas étonnant qu'on les capture plus tôt au Dahomey où les eaux sont plus chaudes.

En conclusion, les jeunes stades post-larvaires (4 épines rostrales) quittent la mer pour pénétrer dans le chenal de Cotonou. A ce stade, ces post-larves ont une nage relativement rapide; aidées par le courant, elles remontent facilement jusqu'à Zogbo situé à environ 8 kilomètres de la mer.

4 BIOLOGIE EN EAU SAUMATRE

De 1962 à 1964, le lac Nokoué a été constamment en communication avec la mer par le chenal de Cotonou. Les eaux de cette lagune sont salées de décembre à juin et douces d'août à novembre. Lors de la présence d'eaux douces, il n'y a plus de crevettes, sauf à l'état sporadique, dans des zones dépourvues de courant (Zogbo, Awansouri) où la salinité descend à 0,5 ‰. Dans le cours inférieur de l'Ouémé et de la Sô, nous avons constaté que les crevettes suivent les eaux saumâtres jusqu'à leur limite amont (30km de la mer) durant la période sèche (mars et avril). C'est ainsi qu'en avril 1964, nous avons constaté que la limite des eaux saumâtres atteignait Kessounou sur l'Ouémé (0,64‰) et Quinto-Aoué sur la Sô (3,21‰) (Fig.1).

4.1 Croissance

4.1.1 Technique. Des échantillonnages de populations sont effectués mensuellement en quatre stations (Fig.1), afin d'étudier la relation entre la salinité et la densité des populations et aussi afin de suivre la croissance des crevettes. La première station, celle dont les eaux sont relativement les moins salées, est située dans la lagune de Porto-Novo. Cette lagune est reliée au lac Nokoué par divers bras, en particulier par le Toché. Les crevettes qui s'y trouvent ne proviennent vraisemblablement que du lac Nokoué, car la distance entre Porto-Novo et Lagos (100 km) est trop importante pour que les crevettes arrivent habituellement par cette seconde voie lagunaire. Deux stations sont situées dans la lagune de Nokoué en une région réputée pour sa richesse en P. duorarum: Zogbo et Awansouri. Awansouri subit assez directement l'influence des eaux du chenal de Cotonou; Zogbo est une station qui ne subit guère cette influence. La quatrième station est située dans le chenal de Cotonou afin d'étudier plus particulièrement les mouvements de descente des crevettes vers la mer.

Nous avions l'intention d'utiliser un chalut à molettes tel que ceux qui sont employés sur les côtes d'Europe pour la pêche des crevettes côtières (Crangon). La différence très nette entre la biologie des Crangon et celle de P. duorarum a voué cet essai à un échec. En effet, d'une part, les P. duorarum s'ensablent plus nettement que les Crangon durant la journée; d'autre part, les P. duorarum nagent la nuit. C'est pourquoi toutes les pêches de cette étude sont réalisées la nuit.

L'excellente connaissance pratique de l'écologie des P. duorarum lagunaires par les pêcheurs dahoméens nous a conduits à utiliser deux de leurs engins de pêche : l'"Azui" et le "Dohouihoué".

l'Azui est un filet de forme pyramidale qui est traîné par deux pêcheurs. Nous utilisons un Azui de 3,50 m de longueur, dont l'ouverture trapézoïdale est de 1,60 m de hauteur, de 3 m de largeur à la base et de 2,50 m de largeur au sommet; les mailles de ce filet diminuent progressivement de l'ouverture (mailles de 2,5 cm) au fond de la poche (mailles de 0,5 cm).

Le Dohouihoué est un filet similaire disposé dans le courant et maintenu ouvert entre deux piquets plantés dans le sable du fond. Nous utilisons un Dohouihoué de 7 m de longueur; il possède une ouverture rectangulaire de 1,80 m de hauteur et de 4 m de largeur. Les mailles de ce filet mesurent 2,7 cm à l'ouverture et 0,6 cm au fond de la poche.

Afin de pouvoir comparer les diverses pêches entre elles, l'Azui est traîné entre 4 piquets de façon à parcourir 500 m à chaque circuit; généralement, il est effectué 4 tours, soit 2 000 m de parcours, afin d'obtenir un échantillonnage satisfaisant de la population. Le Dohouihoué est toujours monté dans le chenal pendant le reflux au début de la nuit, durant 4 heures consécutives.

Dans les quatre stations étudiées, il a été mesuré un total de 7.673 P. duorarum pour les prélèvements mensuels de décembre 1962 à avril 1964. L'échantillonnage le plus élevé est de 619 individus. Il a été capturé 931 crevettes à Porto-Novo en 7 échantillonnages, 2.225 à Zogbo en 11 échantillonnages, 2.776 à Awansouri en 12 échantillonnages et 1.741 dans le chenal de Cotonou en 10 échantillonnages. Il faut noter que les chiffres des prélèvements inférieurs à 30 P. duorarum ne sont retenus que pour l'examen de la densité des quatre populations étudiées.

Chaque crevette est mesurée à l'aide d'un pied à coulisse dont la précision est de 1/50 de mm; en fait, l'erreur absolue des mesures effectuées est égale à 1/10 de mm.

La longueur de chaque crevette est mesurée sur le céphalothorax entre la base du creux orbitaire droit et le milieu de la partie distale postérieure de la carapace.

La relation entre cette longueur du céphalothorax et la longueur totale de la crevette a été étudiée par Iversen et Idyll (1960) et l'on peut dire que la longueur du céphalothorax est égale au quart de la longueur totale, sans tenir compte de la légère différence de cette relation entre les mâles et les femelles.

Enfin, dans cette étude de la croissance, il n'est pas tenu compte de la différence de croissance entre les mâles et les femelles, car il est difficile de distinguer le sexe des jeunes crevettes, le petasma des mâles et le thelycum des femelles ne sont pas encore suffisamment différenciés.

4.1.2 Résultats

4.1.2.1 Densité de population et salinité. Pour chaque prélèvement dans les quatre stations étudiées, le Tableau I donne le total des crevettes capturées par unité de surface (parcours de l'azui ramené à 1 000 m pour Porto-Novo, Zogbo et Awansouri) ou par pêche au dohouihoué durant 4 heures dans le chenal de Cotonou. Le second chiffre entre parentèse exprime la salinité ‰ au moment du prélèvement.

Les Fig. 2 et 3 représentent graphiquement les salinités et les densités de populations pour chacune des quatre stations étudiées. De l'examen de ces graphiques, il ressort que la densité de population est en relation avec la salinité, en ce sens que les crevettes disparaissent lorsque les eaux deviennent douces; ainsi à Porto-Novo, il n'y a pas de P. duorarum si la salinité est inférieure à 0,5‰. Dans des eaux de faible salinité (0,5 à 1‰) il peut y avoir des crevettes (Awansouri et Zogbo, août à novembre 1963), mais la densité est faible. C'est à partir d'une salinité de 5‰ que les crevettes peuvent être abondantes (Porto-Novo, 19 février 1963). Enfin, c'est généralement au moment des fortes salinités que la densité des populations est maximale, en particulier à Zogbo et à Awansouri.

Si l'on compare les graphiques des 4 stations, on constate qu'à Porto-Novo P. duorarum est nettement saisonnière, alors qu'elle est capturée durant la plus grande partie de l'année à Zogbo et à Awansouri. Quant au chenal de Cotonou, le mouvement de descente des crevettes vers la mer est moins directement lié aux salinités que dans les stations lagunaires.

Il faut signaler enfin que les populations de 1964 sont, dans leur ensemble, moins denses que celles de 1963.

On peut conclure que les Penaeus en cours de croissance vivent aisément dans une eau de salinité minimum de 1‰ mais qu'elles ne sont abondantes qu'en eau de salinité égale ou supérieure à 5‰ et cela jusqu'à une salinité comparable à celle de l'eau de mer.

4.1.2.2. Croissance. On peut estimer que la méthode rigoureuse des prélèvements de crevettes (azui ou dohouihoué) permet un échantillonnage satisfaisant de la population au lieu de la pêche et que les différents prélèvements sont donc comparables entre eux.

L'étude graphique de la croissance donne lieu à la constitution d'histogrammes pour chacun des prélèvements mensuels dans les quatre stations. C'est dans ce but qu'à la suite de leur mensuration, les crevettes sont groupées par classes de 2 en 2 mm; chaque classe est figurée par son pourcentage afin de permettre la comparaison entre les histogrammes. Pour chaque prélèvement, nous avons établi le "mode" et la "moyenne arithmétique". Les Fig. 4 et 5 donnent les graphiques du mode et de la moyenne de

TABLEAU I

Densités de populations et salinités

Date	Porto-Novo	Zogbo	Awansouri	Chenal
5.12.62			28 (8,42)	
7. 1.63			82 (21,7)	
11. 1		48 (22,7)		
25. 1	0 (0,49)			
14. 2			154 (29,20)	
19. 2	314 (5,9)			
22. 2		98 (29,2)		
1. 3				269 (32)
20. 3	250 (9,3)			
22. 3				149 (33,2)
27. 3			413 (33,95)	
29. 3		363 (32,95)		
11. 4				44 (30,55)
12. 4			260 (29,29)	
16. 4		130 (27,47)		
23. 4	136 (10,95)			
16. 5			133 (23,48)	
21. 5				50 (30,08)
24. 5		78 (25,77)		
30. 5	112 (6,0)			
14. 6			51 (22,70)	
20. 6				34 (23,06)
25. 6		60 (19,33)		
27. 6	0 (0,18)			
17. 7			46 (9,92)	
19. 7				98 (6,02)
25. 7		101 (5,57)		
30. 7	0 (0,18)			
14. 8			38 (1,0)	
16. 8				17 (1,0)
26. 8		51 (0,98)		
16. 9				0 (0,18)
17. 9			13 (0,57)	
18. 9		75 (0,57)		
21.10				2 (0,12)
23.10			6 (0,57)	
4.11		3 (0,57)		
13.11				0 (0,25)
15.11	0 (0,12)			
18.11			15 (0,83)	
28.11		7 (0,96)		
13.12				0 (32,61)
18.12			29 (16,31)	
23.12	0 (0,18)			
27.12		96 (22,88)		
8. 1.64	0 (0,75)			
13. 1				70 (23,35)
15. 1			97 (20,72)	
21. 1		124 (25,77)		
10. 2				62 (31,98)
13. 2	20 (2,36)			
19. 2		81 (32,74)		
24. 2			65 (34,20)	
12. 3				407 (34,85)
13. 3	34 (11,71)			
19. 3		15 (34,20)		
24. 3			97 (33,57)	
10. 4				554 (34,02)
16. 4	22 (10,37)			
20. 4		67 (29,42)		
24. 4			194 (30,18)	

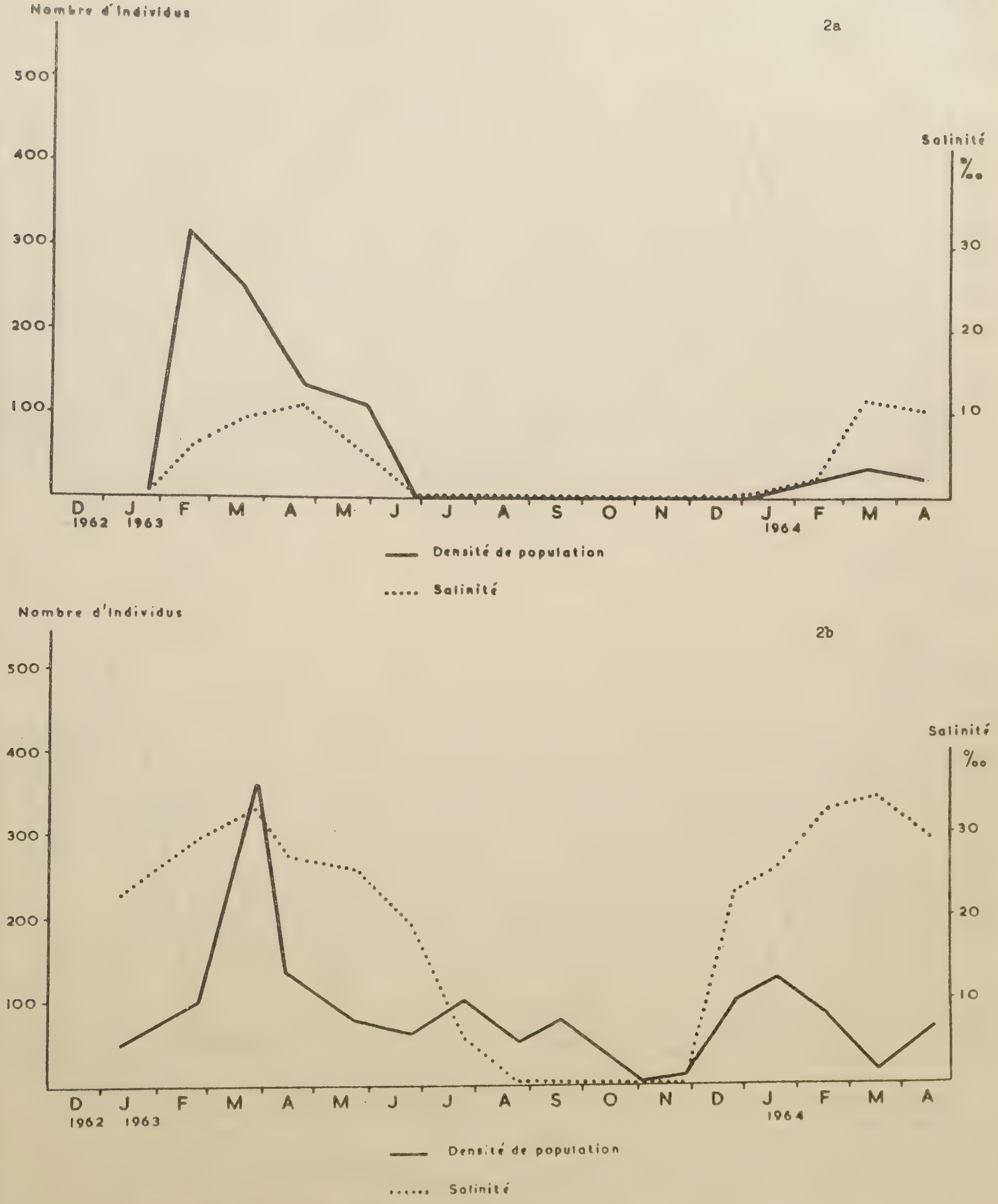
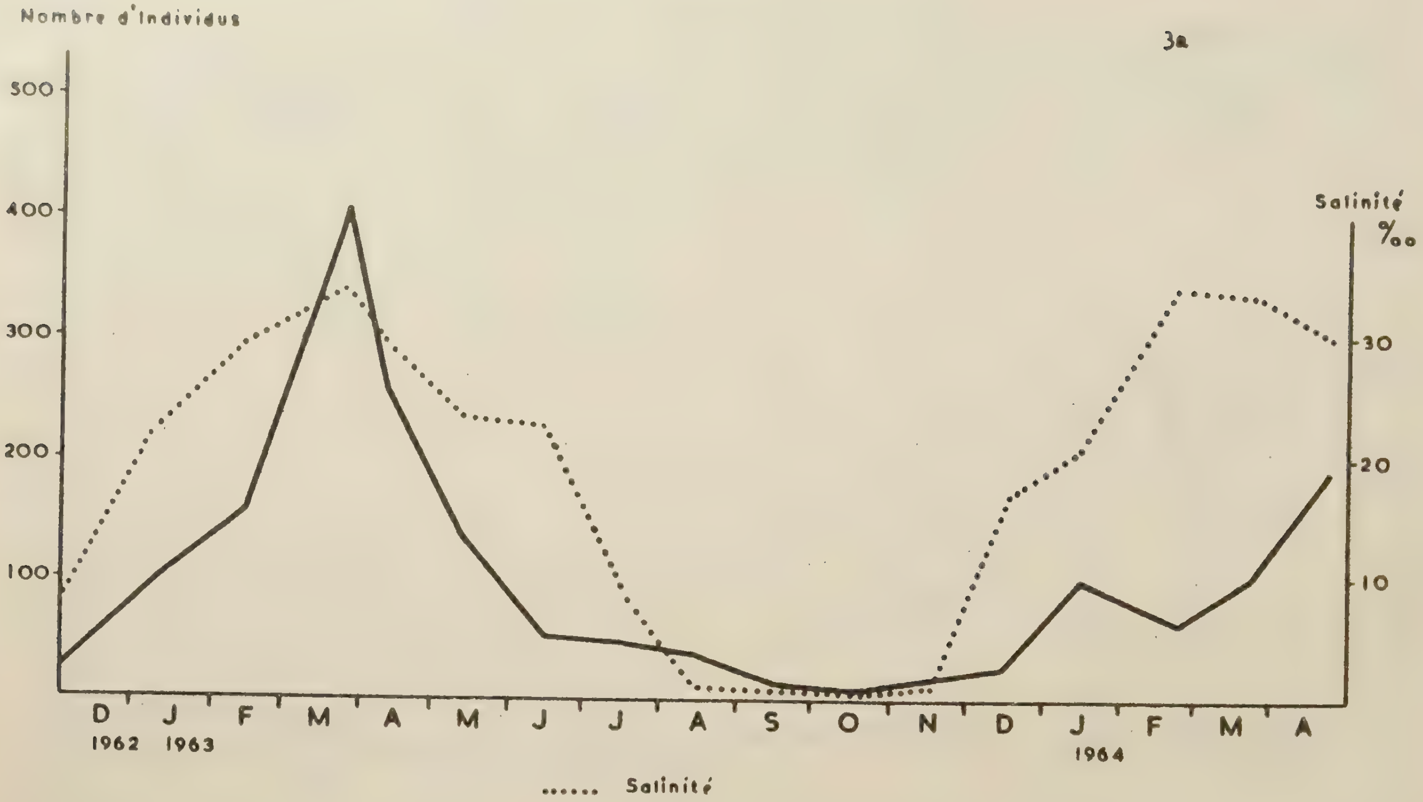


Fig. 2a Graphique des variations de la salinité de l'eau et de la densité de population des Penaeus duorarum à Porto-Novo.

2b A Zogbo.



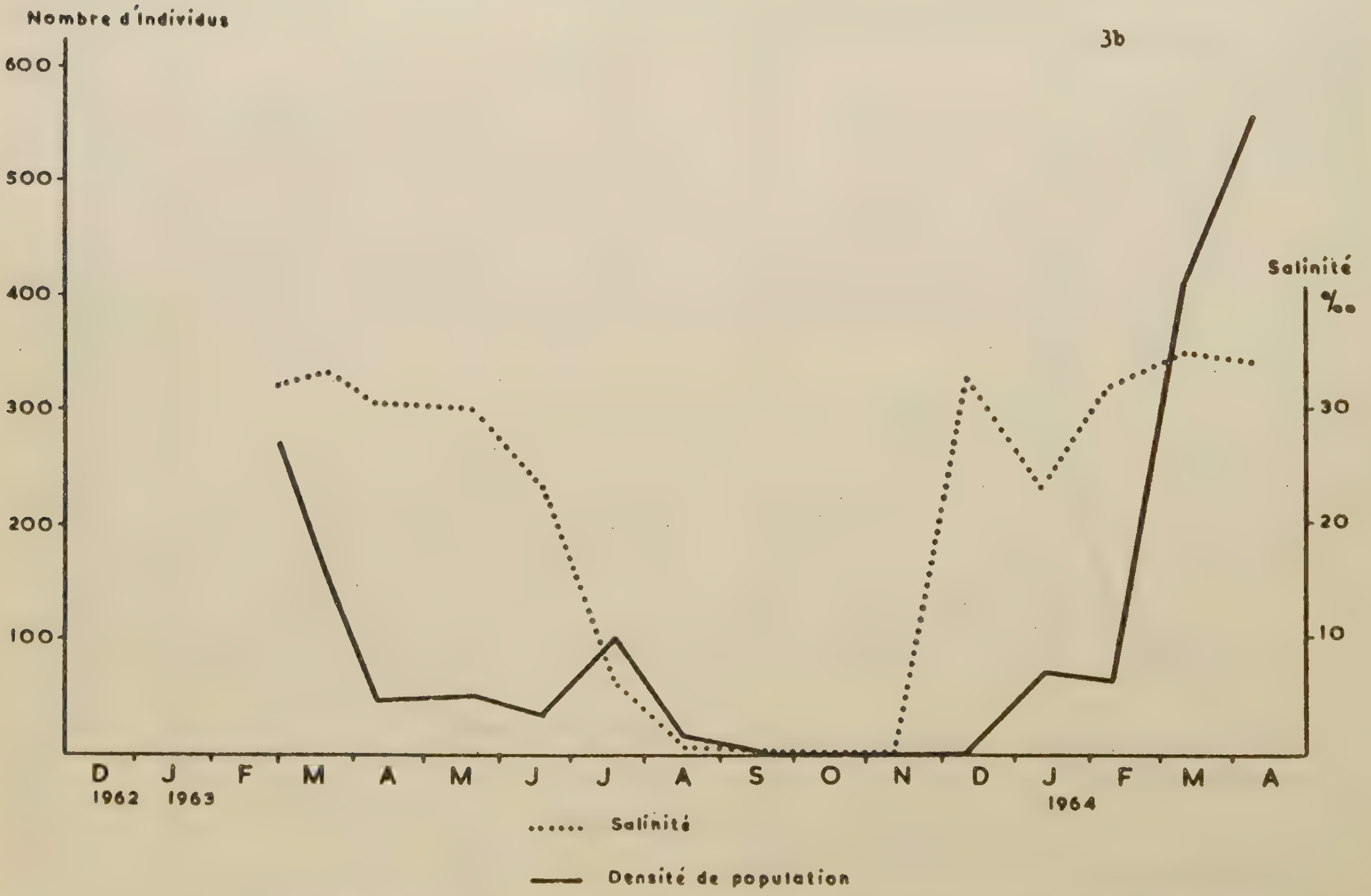
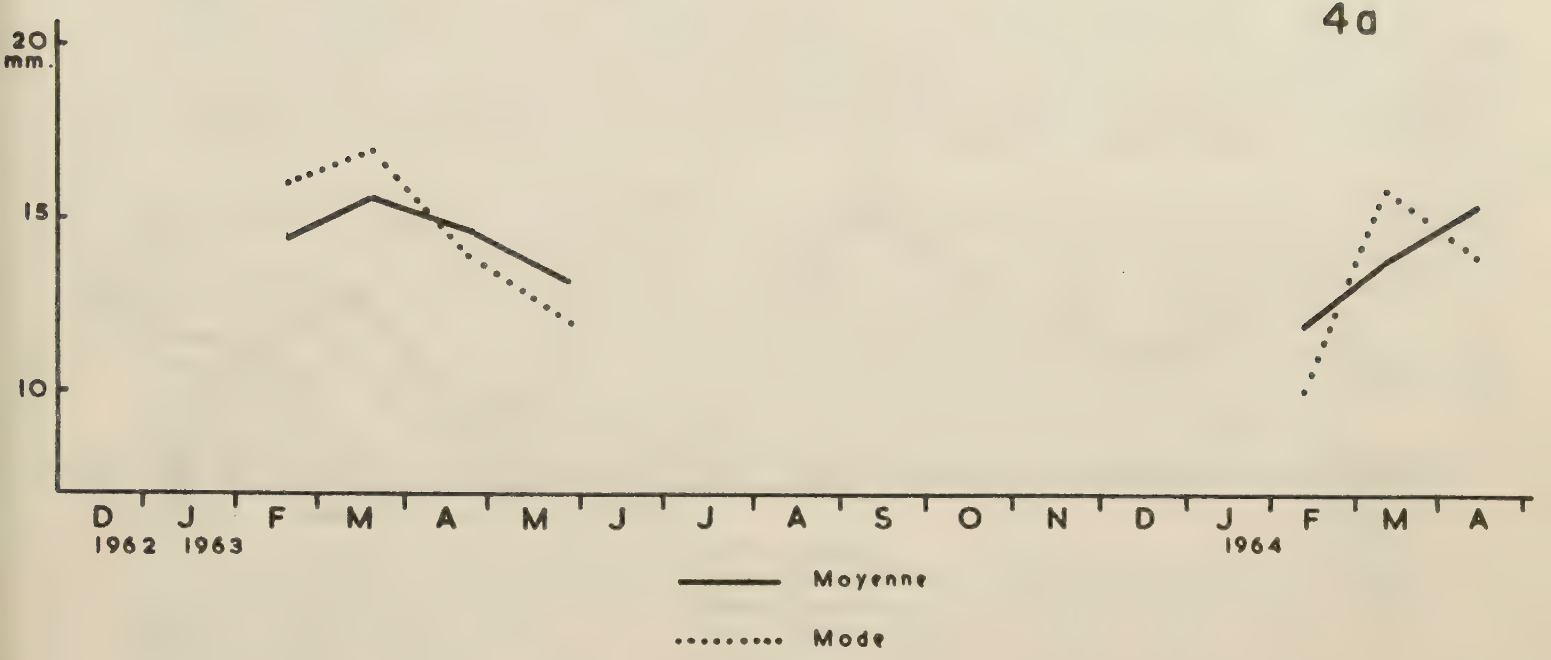


Fig. 3a Graphique des variations de la salinité de l'eau et de la densité de population des Penaeus duorarum à Awansouri.

3b Dans le chenal de Cotonou.



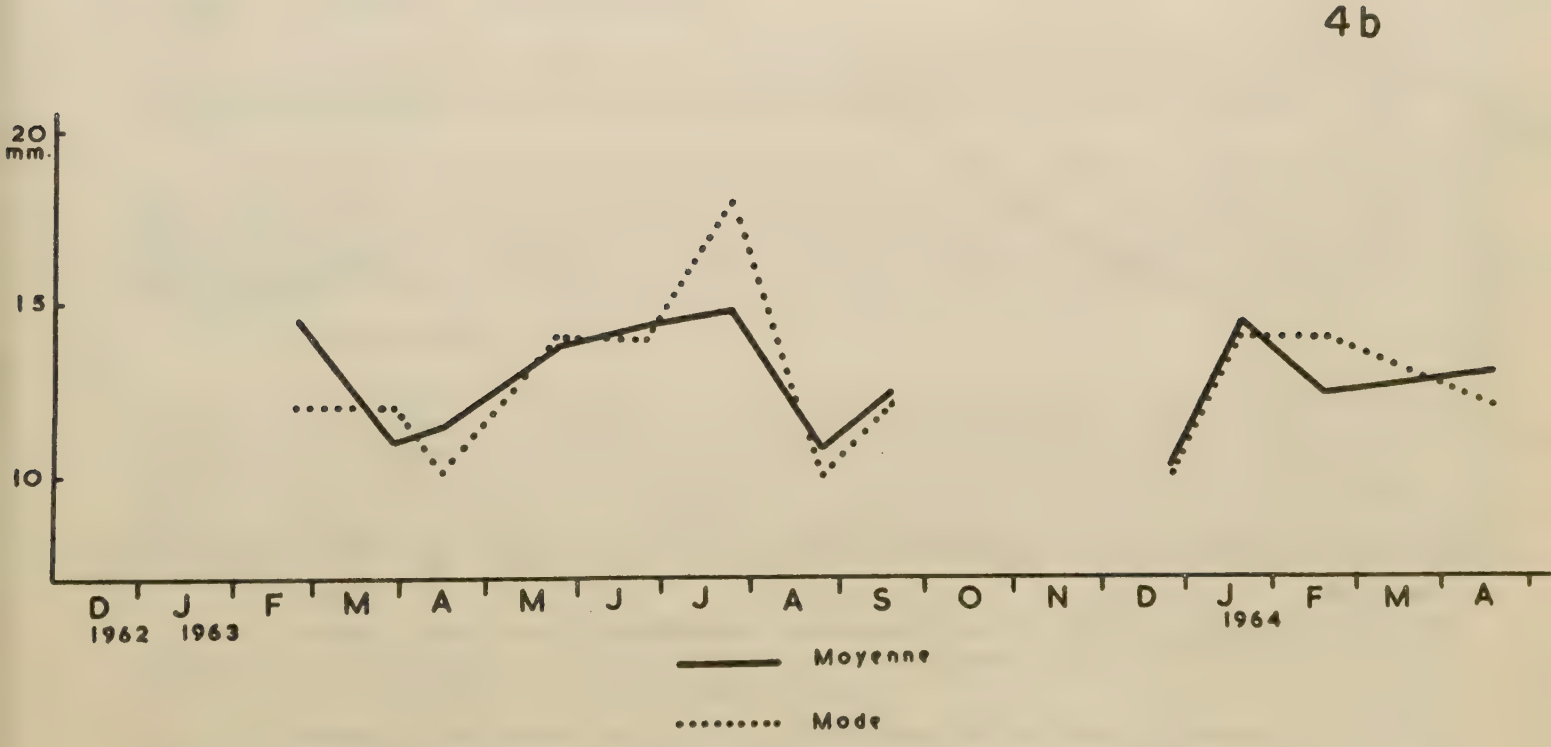


Fig. 4a Graphique des variations du mode et de la moyenne à Porto-Novo.

4b A Zogbo.

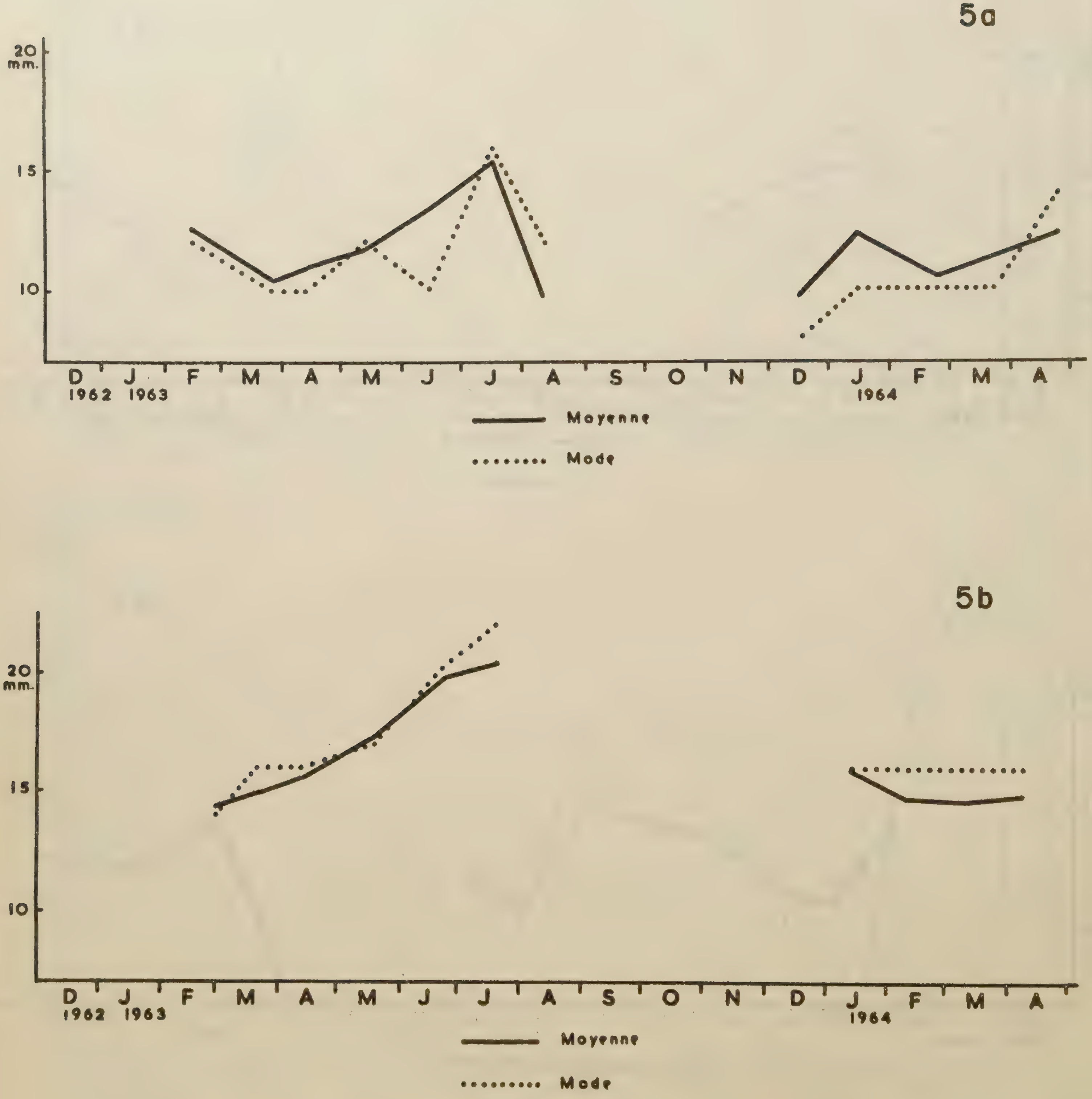


Fig. 5a Graphique des variations du mode et de la moyenne à Awansouri.
5b Dans le chenal de Cotonou.

l'ensemble des prélèvements par station. Il faut rappeler que la moyenne arithmétique est généralement plus représentative de la croissance que le mode. Nous rappelons qu'il n'a pas été tenu compte des échantillonnages inférieurs à 30 individus.

L'examen de ces deux graphiques ne permet pas de caractériser la croissance des diverses populations. Ceci se comprend aisément pour le chenal de Cotonou où l'on ne capture que des crevettes relativement grandes en cours de descente vers la mer; il faut remarquer que la moyenne varie de 14,47 mm (février 1963) à 20,73 mm (juillet 1963) ce qui prouve que la descente ne correspond pas à une dimension précise, mais que les crevettes mesurent généralement de 15 à 20 mm de longueur du céphalothorax.

L'examen des stations lagunaires ne permet pas de suivre nettement la croissance des crevettes durant leur séjour en eau saumâtre. En effet, durant toute la phase saumâtre, il entre constamment de jeunes crevettes dans la lagune. Cependant, la population d'Awansouri présente la croissance moyenne (moyenne arithmétique) la plus importante entre les 27 mars et 17 juillet 1963 (16 semaines), soit 5 mm de longueur du céphalothorax. Cet accroissement correspond à 20 mm d'allongement total du corps; l'allongement moyen total serait donc de 1,3 mm par semaine. Or, selon Kutkuhn (1966), l'allongement de P. duorarum en Floride est de 3,4 mm, ce qui a été constaté avec rigueur sur des crevettes marquées. Mais cette différence entre les crevettes du Dahomey et celles de Floride ne peut être significative, car il ne s'agit au Dahomey, que de croissance moyenne d'une population dont les individus se renouvellent partiellement au cours des mois successifs.

Il est intéressant de rappeler que les crevettes les plus grandes, capturées en lagune ou dans le chenal, atteignaient une longueur céphalothoracique de 28 mm alors qu'aux Etats-Unis d'Amérique, en Floride (Tabb, Dubrow and Jones, 1962), elles ne dépassent pas la longueur de 20 à 22 mm. Nous retrouvons donc ici ce qui avait déjà été constaté pour les post-larves. Les P. duorarum du Dahomey sont donc un peu plus grandes que celles de la Floride. Est-ce dû à un facteur somatique ou génétique ?

4.2 Etat des glandes génitales

Les glandes génitales des femelles les plus grandes du lac Nokoué ont été disséquées et examinées au microscope. Il s'agit de femelles mesurant de 22 à 28 mm de longueur céphalothoracique, ce qui correspond à une longueur totale d'environ 10 cm.

Les ovaires de ces femelles sont transparents ; les ovules sont clairs, apparemment dépourvus de vitellus et leur diamètre ne dépasse pas 41,5 µ. Il est bien évident que ces femelles sont nettement juvéniles et encore très éloignées de leur maturité; elles sont au stade "D" de King (1948), c'est-à-dire que les ovaires peu développés ont une teinte laiteuse; aucun stade "E" (ovaires jaunâtres) n'a été pris en lagune.

4.3 Alimentation

Un important travail de Hall (1962) relate l'examen des contenus stomacaux de plusieurs espèces de Penaeides de la Malaisie. L'alimentation de ces Penaeides est principalement animale (Polychètes, Mollusques, Crustacés, Poissons) et plus ou moins végétale. Eldred et al. (1961) constatent, à la suite d'autres auteurs, que P. duorarum est omnivore : les débris stomacaux sont principalement animaux (Polychètes, Crustacés, Mollusques, etc.) mais comportent également des végétaux (feuilles, rhizomes, algues).

Au Dahomey, nous avons examiné les contenus stomacaux de 20 P. duorarum mesurant de 12 à 18 mm de longueur du céphalothorax, prélevés dans l'échantillonnage de la population d'Awansouri (12 avril 1963).

Le Tableau II présente les principaux éléments des contenus stomacaux. L'importance de l'aliment envisagé est figurée par des croix: + = peu abondant; ++ = abondant; +++ = très abondant.

TABLEAU II

Contenus stomacaux

Numérotation des crevettes	Poissons	Crustacés benthiques	Crustacés planctoniques	Polychètes	Mollusques	Végétaux
1	++	++				+
2	++	++				+
3	++	+++				
4	++			++		+
5	+	+		+	+	+
6	+++	+				+
7	++	+		+		+
8	+	++	+	+		+
9	+	++	+			
10	+	+	+			+
11	++	+	+			
12	++	++				+
13	+	+	+			
14	++	+	+			+
15	+++					+
16	++	+				+
17	++	+	++			
18	++	+				
19	+	++				
20	++	++				+

De l'examen de ce tableau, il ressort que les crevettes de cette population d'Awansouri se nourrissent principalement de poissons et de crustacés. Il s'agit de petits poissons dont les vertèbres mesurent de 0,25 à 0,35 mm de longueur; dans un seul estomac il est trouvé des écailles relativement grandes mesurant 2,55 mm de diamètre. Les crustacés sont très divers, principalement benthiques (Amphipodes, petits Décapodes) quelquefois planctoniques (Copépodes). Les Polychètes sont beaucoup moins fréquentes, ce qui est probablement lié à leur densité plus faible que celle des crustacés et des poissons dans la lagune. Il n'a été trouvé de mollusques que dans un seul estomac: il s'agit de Gastropodes. Les végétaux sont fréquemment représentés, mais toujours en faible quantité. Il y a d'autres débris difficilement identifiables (Chétognates, etc.).

En résumé, les P. duorarum de la lagune semblent être principalement carnivores avec un léger apport végétal.

4.4 Expérimentation

Quelques essais d'élevage sont réalisés, soit en aquarium de verre, soit en bacs plastiques. A cause de la fragilité des crevettes, celles-ci, pêchées la nuit à Awansouri dans les nasses, sont transportées en cuvettes jusqu'au laboratoire, car elles supportent mal le transport à sec.

Elevage en grand aquarium. Les crevettes sont normalement ensablées durant le jour; seuls les yeux sont visibles à la surface du sable; la nuit, les crevettes nagent dans l'aquarium. La nourriture est constituée par des poissons morts, divers crustacés et quelques débris végétaux; les crevettes semblent préférer les poissons aux crustacés. Ces crevettes vivent dans des conditions satisfaisantes puisque les mues, qui sont toujours un moment critique dans la vie des crustacés, s'effectuent normalement.

Elevage en petits aquariums. Dans le but de réaliser des élevages comparables, on utilise 7 petits aquariums de verre d'une contenance de 5 litres d'eau. Les divers aquariums contiennent des eaux de salinité croissante : 0,07‰; 2‰; 5‰; 10‰;15‰;20‰; 33‰. Les crevettes utilisées mesurent de 9 à 18 mm de longueur du céphalothorax et sont prélevées après un séjour de 24 heures dans le grand aquarium de 60 l d'eau (salinité 20‰). On dispose 5 crevettes par petit aquarium et l'expérience dure 5 jours, car la petite dimension des aquariums ne permet que des essais très limités dans le temps sur l'influence de la salinité.

En eau douce (salinité 0,07‰), les crevettes meurent après 2 à 6 heures d'expérimentation.

Dans une eau de salinité de 2‰, les crevettes meurent après 3 à 24 heures d'expérimentation.

Dans les eaux de salinité de 5‰, 10‰, 15‰ et 33‰, les crevettes vivent facilement durant les 5 jours de l'expérience. Il y a même des mues dans plusieurs aquariums, aussi bien dans les eaux de salinité de 5‰ que dans celles de 33‰.

Ces expériences permettent d'affirmer que les P. duorarum vivent aisément dans des eaux de salinité variant entre 5 et 33‰; elles ne peuvent subsister longtemps dans des eaux de salinité égale ou inférieure à 2‰, au moins dans les conditions de l'expérience, c'est-à-dire lorsque les crevettes sont prélevées dans une eau de salinité de 20‰ pour être portées directement dans les aquariums à salinité égale ou inférieure à 2‰.

En résumé, ces divers essais expérimentaux prouvent que P. duorarum ne peut vivre en eau douce. D'autre part, les crevettes mesurant plus de 9 mm de longueur du céphalothorax ne peuvent supporter le passage brusque d'une salinité de 20‰ à une salinité égale ou inférieure à 2‰.

Les pêches du 14 août 1963 à Awansouri (salinité 1‰) et du 26 août 1963 à Zogbo (salinité 0,98‰), prouvent que des P. duorarum mesurant en moyenne 11 mm de longueur du céphalothorax peuvent supporter pendant quelque temps cette faible salinité; mais l'abaissement de salinité s'est produit lentement dans ces deux stations au cours des mois de juillet et d'août. Il est également possible que certaines crevettes soient plus résistantes et que les autres crevettes soient descendues vers la mer ou aient péri en lagune.

5 MATURATION EN MER

Avant 1962, aucune capture de P. duorarum n'avait été signalée en mer au large de Cotonou. C'est pourquoi le problème de la reproduction de cette espèce en lagune s'est posé. Mais, comme cette espèce ne se reproduit qu'en mer sur les côtes atlantiques des Etats-Unis, il semblait difficile d'admettre un cycle biologique différent sur les côtes équatoriales africaines. D'autre part, les pêcheurs de la lagune de Cotonou reconnaissent qu'en cas de fermeture naturelle de la lagune pendant plusieurs années (comme cela s'est produit dans le passé), on ne pêche plus de P. duorarum dans la lagune, mais seulement des Macrobrachium.

5.1 Localisation

En octobre 1962, nous avons examiné les pêches du chalutier "Avrekété" au large de Cotonou. Le chalut est traîné sur des fonds de 12 à 17 mètres. Les Penaeides capturées sont des Parapenaeopsis atlantica abondantes sur ces fonds et de rares spécimens de Penaeus kerathurus; aucun P. duorarum n'a été capturé.

En 1963, le chalutier "Zéphir" a pêché par des fonds de 10 à 40 m; grâce à l'obligeance de M. Paraiso, Directeur du Service des pêches du Dahomey, et de la Direction de la SOCAP, nous avons examiné les pêches de ce chalutier de juin à fin août.

Par des fonds de 10 à 20 m (de 1 à 8 km au large), le chalutier ne prenait que des espèces de Penaeides pêchées antérieurement par l'"Avrekété". Par des fonds de 20 à 40 m (entre 8 et 18 km au large), le "Zéphir" a capturé des P. duorarum en nombre appréciable. Il s'agit de femelles plus grandes que celles de la lagune. Beaucoup d'entre elles mesurent de 40 à 50 mm de longueur du céphalothorax; la plus grande longueur observée à Cotonou est de 50,9 mm ce qui correspond à une crevette de longueur totale égale à 24 cm. Cette longueur est comparable à la plus grande longueur (50 mm) signalée par Iversen et Idyll (1960) sur les côtes de Floride. D'autre part, à Lagos (26 août 1963), nous avons examiné une femelle mesurant 52 mm de longueur du céphalothorax. Chez les adultes, comme c'est le cas pour les autres stades de croissance, les P. duorarum du Dahomey sont un peu plus grandes que celles des côtes de Floride.

Les résultats les plus intéressants de la localisation des P. duorarum en mer sont obtenus par les pêches expérimentales du navire océanographique de l'Office de la Recherche Scientifique et Technique d'Outre-Mer "Ombago" en octobre 1963 (Crosnier et Berrit, 1966). Le littoral du Dahomey et celui du Togo ont été sillonnés de la côte jusqu'à 20 km au large.

Parmi les 29 chalutages réalisés et inventoriés (Paraiso, 1964), 8 seulement contenaient des P. duorarum (Fig. 6, lettres A à H). La plupart de ces chalutages se situent dans la zone vaseuse de 40 à 55 m de profondeur (bande pointillée de la Fig. 6). Cette bande vaseuse est localisée entre la zone de sable coquillier grossier et la zone rocheuse coralliaire. D'autre part, elle correspond à la couche d'eaux marines située au-dessus de la thermocline.

On peut donc estimer qu'au large du Dahomey, les P. duorarum vivent principalement sur des fonds qui sont à 12 km de la côte et qui ne mesurent que de 2 à 5 km de largeur (Fig. 6). Au Nigéria, de Vriès et Lefevere (1966) signalent des captures de P. duorarum entre 18 et 45 m de profondeur.

Les P. duorarum pris au Dahomey par des fonds inférieurs (20 à 40 m) durant l'été

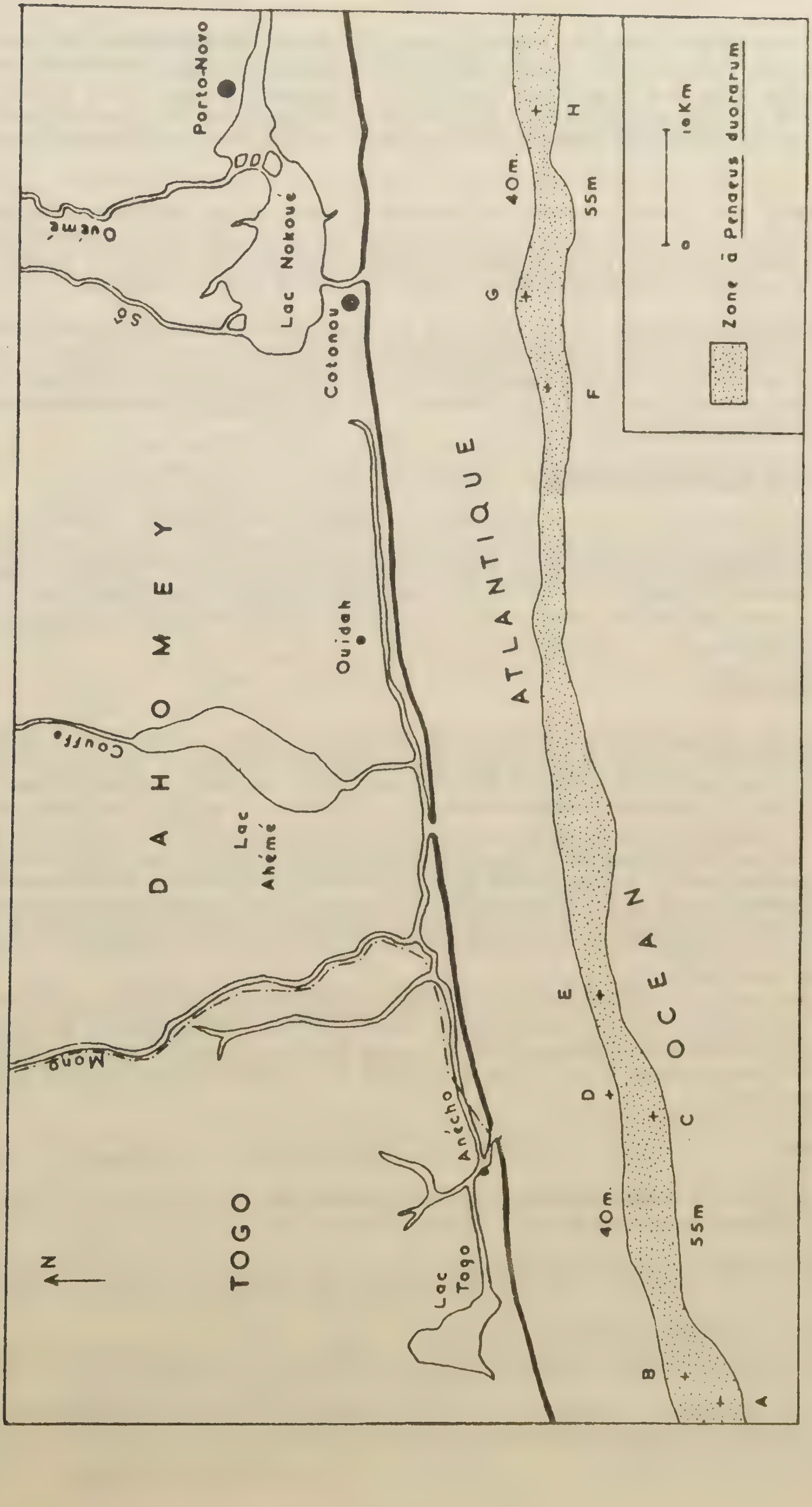

N
TOGO
Lac Togo
Anécho
Mono
D A H O M E Y
Lac Ahémé
Couffo
Ouidah
Cotonou
Lac Nokoué
Sô
Ouémé
Porto-Novo
ATLANTIQUE
OCEAN
40m.
55m
A
B
C
D
E
F
G
H
Zone à Penaeus duorarum
0
10Km

Fig. 6 Carte des fonds marins à *Penaeus duorarum* le long du littoral dahoméen.

de 1963 étaient toutes des femelles. Selon l'avis du patron du chalutier, il n'en a pas été pris sur ces fonds, ni en hiver, ni au printemps; il s'agit peut-être de femelles qui viennent pondre dans des eaux moins profondes. Cependant en mai 1964, un autre chalutier a pêché des P. duorarum lors des chalutages sur des fonds de 30 à 40 m; il s'agit de crevettes de diverses tailles, mais toujours plus grandes que les crevettes de la lagune.

D'autre part, nous avons examiné des documents non publiés dûs aux recherches de Longhurst et Mann. Le long des côtes de la Nigéria (entre Lagos et la Kulana River), il a été capturé, en 1963, des P. duorarum sur des fonds variant entre 15 et 60 m, alors que les chalutages ont été effectués entre 10 et 250 m de profondeur.

Sur les côtes américaines (Floride), les P. duorarum vivent principalement sur des fonds de 18 à 36 m; la plus grande profondeur observée est de 70 m (Idyll, 1964). Ces fonds sont constitués par de la vase avec 20% de sable coralliaire. Il est donc intéressant de souligner qu'au large du Dahomey, les P. duorarum vivent généralement plus profondément qu'en Floride.

5.2 Etat des glandes génitales

Les plus grandes femelles capturées au large de Cotonou en juin et juillet 1963 ainsi que celles examinées à Lagos (août 1963) possèdent des ovaires volumineux de couleur jaune verdâtre, c'est-à-dire entre les stades "Y" et "R" de King (1948); ce sont donc des ovaires proches de la maturité. Les plus grands ovules mesurent 3/10 de mm de diamètre; cette dimension correspond à celle des ovules mûrs des P. duorarum de Floride (Dobkin, 1961).

6 ASPECT ECONOMIQUE

La pêche de P. duorarum est actuellement importante dans le lac Nokoué alors qu'elle est réduite dans le lac Ahémé (Fig. 6); c'est une situation inverse de celle du début de ce siècle (Lefebvre, 1908). Une estimation de la pêche annuelle par les nasses et les filets à crevette s'avère difficile. D'après un rapport du Service des Eaux et Forêts du Dahomey, 1957 à 1959, la productivité du lac Nokoué serait de plus de 1 000 tonnes de crevettes par an. Ces chiffres semblent élevés; on peut penser qu'un chiffre de 500 tonnes serait actuellement plus proche de la réalité. Ces crevettes sont vendues aux Dahoméens après avoir été séchées et fumées; une partie de ces crevettes est actuellement exportée vers la France. D'autre part, la pêche de ces crevettes en mer n'a commencé qu'en 1963.

En 1966, des relevés statistiques du Service Dahoméen des Pêches, signalent que les deux usines de congélation de Cotonou ont traité environ 60 tonnes de P. duorarum provenant principalement du lac Nokoué (46 t), puis du lac Ahémé (10 t), de Porto-Novo (2 t) et de l'Océan Atlantique (2 t). Ces crevettes sont expédiées en France après cuisson et congélation.

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A METHOD OF REARING PENAEID SHRIMP LARVAE FOR EXPERIMENTAL STUDIES [1]

by

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Abstract

A description is given of a method used to rear penaeid shrimp from eggs to postlarvae in the laboratory. Six species of shrimp have been cultured, and sufficient numbers of Penaeus aztecus Ives and P. setiferus (Linn.) were reared to supply animals for physiological studies and to stock small experimental ponds.

METHODE D'ELEVAGE DE LARVES DE PENAEIDAE EN VUE D'ETUDES EXPERIMENTALES

Résumé

Description de la méthode employée pour élever en laboratoire des Penaeidae depuis l'oeuf jusqu'aux postlarves. L'élevage a porté sur six espèces, et l'on a obtenu un nombre suffisant de Penaeus aztecus Ives et de P. setiferus (Linn.) pour fournir des animaux aux fins d'études physiologiques et pour charger de petits étangs expérimentaux.

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METODO DE CULTIVO DE LARVAS DE CAMARONES PENEIDOS PARA ESTUDIOS EXPERIMENTALES

Extracto

Se expone el método empleado para cultivar en laboratorio camarones peneidos a partir de los huevos hasta la fase de postlarvas. Se han cultivado seis especies de camarones, y se criaron cantidades suficientes de Penaeus aztecus Ives y P. setiferus (Linn.) con objeto de proporcionar ejemplares para realizar estudios fisiológicos y para poblar pequeños estanques experimentales.

1 INTRODUCTION

Research in the United States during recent years on commercially important species of penaeid shrimp has emphasized the importance of the life stages which occur in offshore waters. The latest informational report of the Shrimp Biological Research Committee of the Gulf States Marine Fisheries Commission (1966) states that "Environmental conditions in the nursery areas can affect the abundance of brown shrimp but the principal cause or causes of these annual fluctuations lies in the Gulf of Mexico." Since almost all penaeid shrimp pass through their larval stages in offshore waters, it is becoming increasingly important to learn more about this stage of their development. Most attempts to study the biology of larval shrimp have been hindered by a lack of larvae with which to work. In fact, the larvae of most species have not even been described.

With the exception of the work of Hudinaga (1942) and Fujinaga (1963) in Japan, nearly all attempts to rear large numbers of penaeid larvae in the laboratory have been unsuccessful. Heldt (1939) and Ewald (1965) succeeded in culturing a few larvae, but the numbers were too small to permit laboratory experimentation. Although Hudinaga was most explicit in his explanation of the methods used to culture larvae of Penaeus japonicus Bate, I have not been able to rear larvae of penaeids from the United States by following his methods.

This paper describes modifications and improvements of the culture techniques described by Cook and Murphy (1966). With this method, sufficient larvae of brown shrimp (P. aztecus) and white shrimp (P. setiferus) have been cultured to supply animals for physiological studies and to stock small experimental ponds. In addition, P. duorarum Burkenroad, Sicyonia brevirostris Stimpson, Trachypenaeus similis (Smith), and Xiphopenaeus kroyeri (Heller) have been reared to postlarvae.

2 METHODS

2.1 Field collections

Female shrimp in spawning condition are taken with a commercial 14-m otter trawl. The length of the tow depends on the amount of fish and trash taken along with the shrimp, but is usually between 10 and 30 min. The catch is deposited directly on the deck; if sorted immediately, the ripe females are not hurt by the brief period out of water. On board the ship, the shrimp are held in a tank through which water is circulated continuously. Circulated water is not essential, however, for by changing the water periodically (every 2 h in hot weather), I have held shrimp in containers of various sizes and shapes for several days. The shrimp are transported from the vessel to the laboratory in 75-l plastic barrels, usually within 24 h of being caught. In extremely hot weather, plastic bags filled with ice are put in the barrels to reduce the temperature. With the temperature reduced in this manner shrimp have been transported more than 120 km with little mortality.

2.2 Laboratory procedures

At the laboratory, the shrimp are placed in 946-l fiberglass tanks (Fig. 1), described by Marvin (1964), containing 560 l of water that has been passed through a 5 μ cellulose filter. The height of the tanks is 61 cm, inside dimensions are 90 x 152 cm at the bottom, and 110 x 168 cm at the top. Before adult shrimp are placed in the tanks, the sodium salt of EDTA /(Ethylenedinitrilo)-tetracetic acid/ is added to the water at a rate of 1 g per 100 l. I have been unable to determine the effect of EDTA, but when it has been added, no unexplained hatching failures or larval mortalities have occurred. On many occasions when EDTA was not used, either the eggs did not hatch, or there were total mortalities of larvae which could not be accounted for. At other times, however, eggs have hatched and larvae have grown to postlarvae in water that did not contain EDTA. At a result, EDTA is added to the water during all phases of the rearing procedure.

As many as 3 shrimp are placed in each tank, depending on the number available. Water in the tanks is recirculated continuously through a crushed oyster shell filter and is aerated vigorously from lead-weighted air stones suspended from the sides of the tank. (The shell contained in the filter is a commercial product processed as a chicken food supplement; it is washed thoroughly before use.) To prevent eggs and larvae from being pumped into the filter, a removable screen is placed over the outlet hose. The screen is a bag made of nylon plankton mesh (0.183-mm mesh opening) attached by elastic bands to a number 11 rubber stopper through which the outlet hose is inserted. A tube of heavy plastic mesh is placed inside the bag to keep it from collapsing. The bag has a surface area of 390 cm^2.

The shrimp that spawn usually do so the first night after they are brought to the laboratory. Ordinarily only about one-third of the shrimp produce viable eggs. Some shrimp do not spawn, but resorb their eggs in a few days; others deposit their spawn in a single mass, and the eggs never develop.

After the shrimp spawn, they are removed from the tank to keep them from eating the eggs. Large numbers of larvae have been hatched in the 946-l tanks, but subsequent survival has been poor. Smaller tanks (90-l capacity) have also been used satisfactorily for hatching (Cook and Murphy, 1966). Only one large shrimp, however, can be held in each of these tanks, and more tanks must be set up to ensure getting viable eggs.

After the eggs have hatched, a number of nauplii are siphoned from the large tank and concentrated on a stainless steel screen attached to the end of the siphon (Fig. 2c). (The nauplii are hardy and are not injured by such handling if they are kept immersed at all times.) They are then placed in an inverted 19-l polyurethane carboy from which the bottom has been removed (Fig. 2). Polyurethane is used because it is non-wettable; almost no mortalities are caused by the young shrimp jumping out of the water and becoming attached to the sides of the carboy.

Aeration is supplied by an air stone in the neck of the carboy just above a rubber stopper through which the air hose runs. This arrangement results in good water circulation which, coupled with the sloping shoulders of the carboy, prevents the food from settling out. Each carboy holds 15 l of filtered water, half of which is replaced daily. When water is removed, a screen (Fig. 2c) is placed over the mouth of the siphon to prevent the loss of larvae. As many as 4,000 larvae have been reared to postlarvae in one of these carboys.

2.3 Food

A diatom, Skeletonema costatum (Greville) Cleve, is added as food at the first protozoeal substage. Normally, 1 ℓ of Skeletonema culture, having an approximate cell count of 2 x 10^8, is added to each carboy at the first feeding. Thereafter, $\frac{1}{2}$ ℓ is added after each daily water change. Other algae, such as Thallassiosira sp., Dunaliella sp., Gymnodinium splendens Lebour, and Exuviella sp., have also been used successfully as food for the protozoeal substages. When culturing shrimp which have relatively large larvae, such as Penaeus aztecus, newly hatched brine shrimp (Artemia sp.) are supplied at the third protozoeal substage. For species with smaller larvae, such as Trachypenaeus similis, brine shrimp are not added until the first mysis substage. The addition of algae is stopped 1 day after the introduction of brine shrimp.

3 EFFECTS OF TEMPERATURE AND SALINITY

Although no extensive experiments have been performed to determine the effects of temperature or salinity on larval development, ranges within which larvae have grown well have been delineated. Water temperature should be kept above 24°C. Rate of larval growth increases with increasing temperature up to 32°C, the highest temperature tried. I regard the range from 28° to 30°C as the most favorable. At salinities above 35 and below 27 ‰, hatching has been inhibited and larvae have died. Low-salinity water can be made usable, however, by adding sea salts.

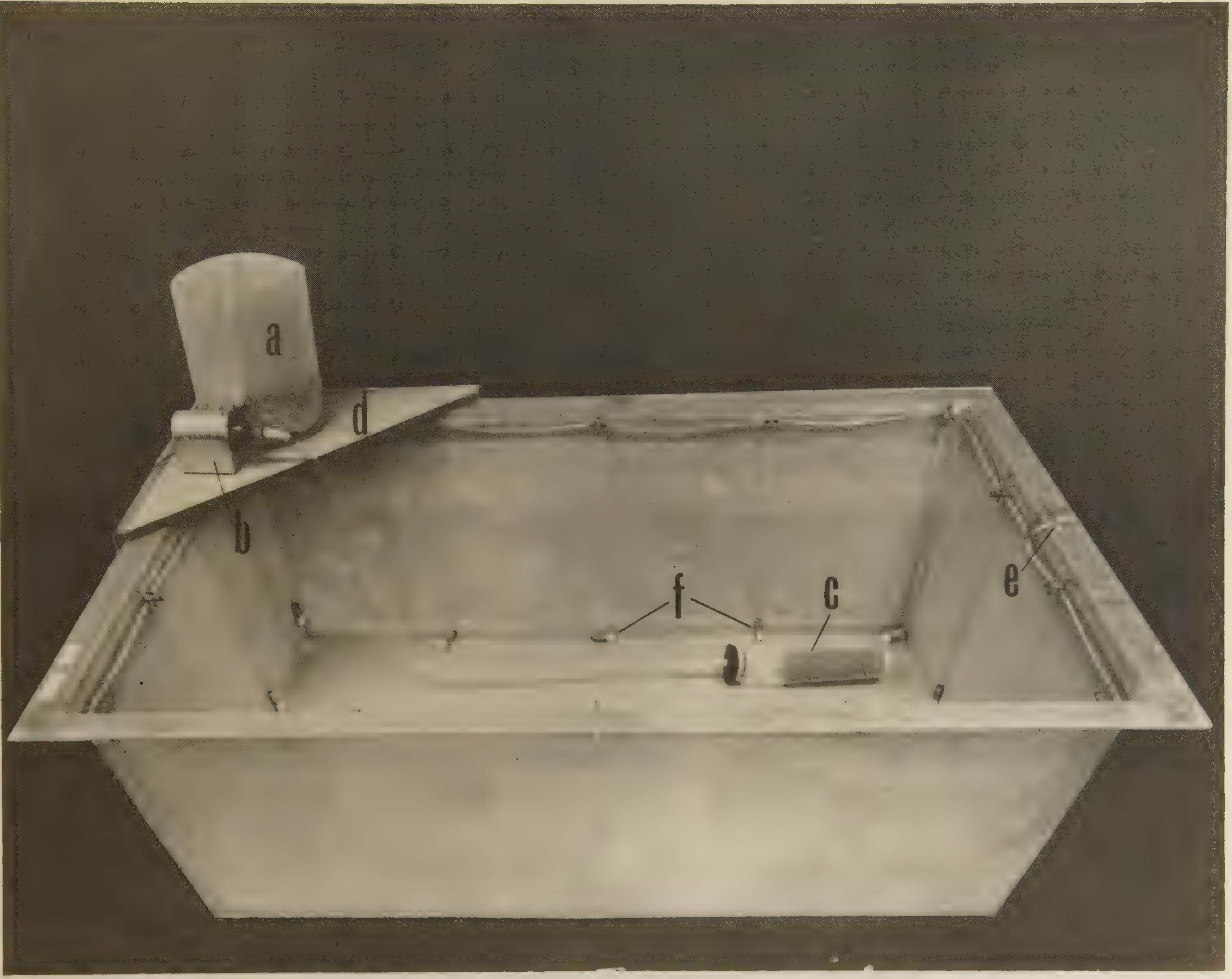

Fig. 1 Fiberglass tank in which shrimp spawn: a, crushed oyster shell filter
b, water pump c, screen filter d, support stand
e, air hose f, air stone and lead weight

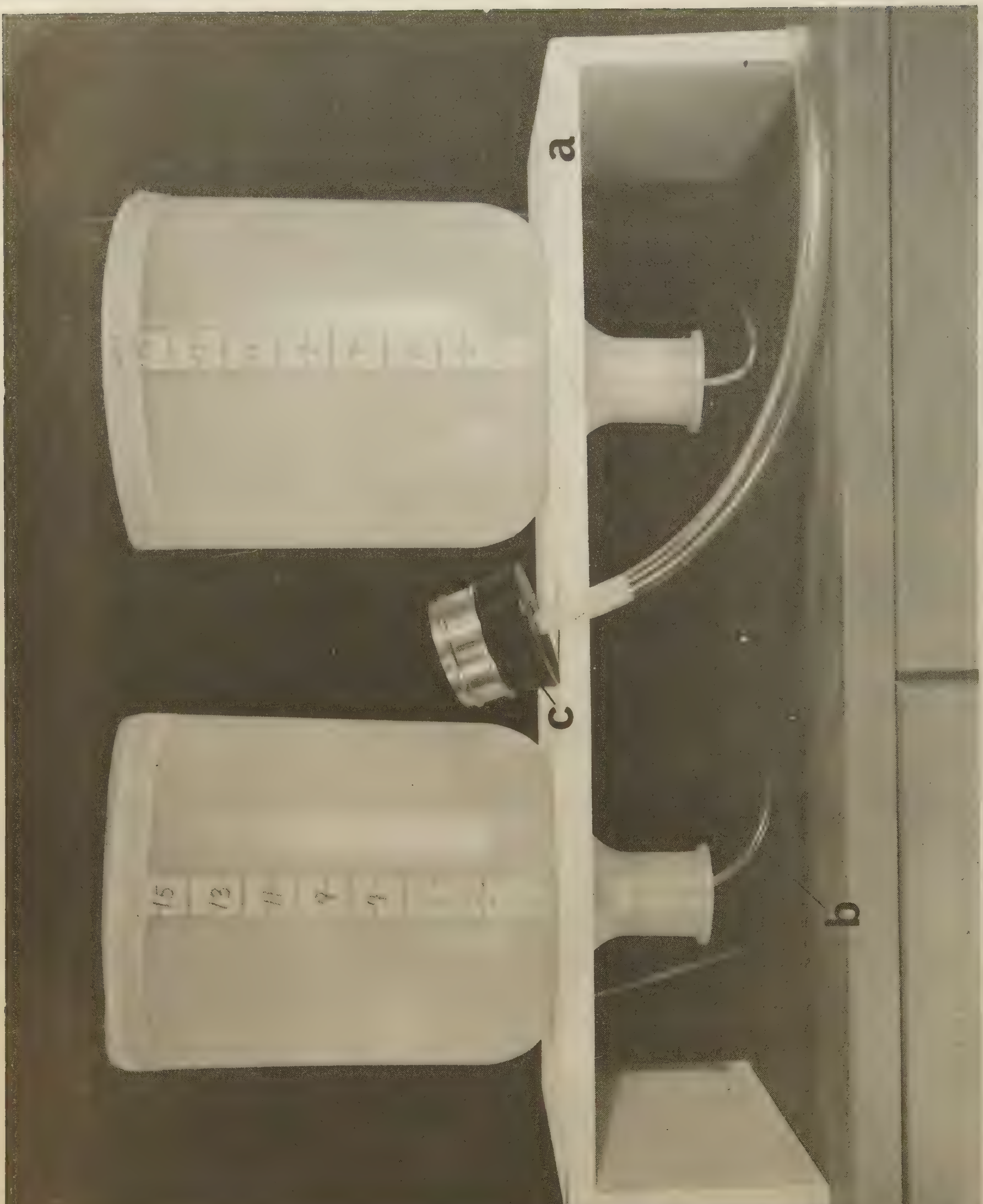

Fig. 2 Polyurethane containers used for culturing larval shrimp:
a, support stand b, air hose
c, screen assembly used to change water and concentrate larvae

4 LARVAL MORTALITY

Larval mortality within the inverted carboys has been variable, depending on the initial stocking rate and the amount of food available. In most experiments the estimated survival from Nauplius I to first Postlarva has been about 50 percent. If carboys are stocked with 4,000 nauplii, an average yield of about 2,000 postlarvae per carboy can be expected. Thus, 20,000 postlarvae could be reared with only 10 carboys. This number should be sufficient for most experiments.

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THE PRAWN FISHERY OF SHARK BAY, WESTERN AUSTRALIA

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Abstract

The Shark Bay prawning industry is based on the species *Penaeus latisulcatus* (western king prawn) and *P. esculentus* (tiger prawn). The history, present status and management of the industry are described. Methods of fishery data collection are described, with details of the use of these and environmental data in examining two hypotheses propounded to explain a fall in total catch in 1965 to 1966.

Equations are presented for carapace length - tail weight - grade relationships.

The importance of distinguishing the contributions of growth and migration to fluctuations of the fishery is illustrated by data on catch, effort and size-composition. Marking is used to measure the effect of migration. Reference is made to a model to explain and quantify these parameters.

A description of nursery areas is given, and the effectiveness of present management measures is discussed.

LA PECHERIE DE CREVETTES DE LA BAIE DU REQUIN, AUSTRALIE-OCCIDENTALE

Résumé

La pêche de la crevette de la baie du Requin repose sur les espèces Penaeus latisulcatus et P. esculentus. La communication traite de l'histoire, de la situation actuelle et du fonctionnement de cette pêche. Elle décrit les méthodes employées pour le rassemblement des données halieutiques et fournit des détails sur l'emploi de ces renseignements et de données écologiques pour examiner deux hypothèses avancées pour expliquer une diminution des prises globales enregistrée en 1965-66.

Des équations sont présentées pour les rapports longueur de la carapace/poids de la queue/qualité.

Pour illustrer combien il importe de déceler les conséquences de la croissance et des migrations sur la dynamique de la pêcherie, des données sont fournies touchant les prises, l'effort de pêche et la composition par taille. On a recours au marquage pour mesurer les effets des migrations. On se sert d'un modèle pour expliquer et quantifier ces paramètres.

Enfin, la communication décrit les frayères et examine l'efficacité des mesures actuelles d'aménagement.

LA PESQUERIA DE LANGOSTINOS DE LA BAHIA SHARK, AUSTRALIA OCCIDENTAL

Extracto

La industria pesquera de langostinos de la Bahía Shark se basa en dos especies, Penaeus latisulcatus (langostino rey occidental) y P. esculentus (langostino tigre). Se describe la historia, la situación actual y la ordenación de la industria. Se exponen igualmente los métodos de recogida de datos pesqueros, detallando su empleo y los datos del medio ambiente para examinar las dos hipótesis que tratan de explicar la disminución de las capturas totales en 1965-66.

Se indican las ecuaciones de la relación longitud-caparazón-peso de la cola. Con los datos sobre captura, esfuerzo y composición por tamaños se ilustra la importancia de distinguir los efectos del crecimiento y de la migración sobre la dinámica de la pesquería. Para medir las consecuencias de la migración se emplea el marcado. Para explicar y cuantificar estos parámetros se hace referencia a un modelo.

Se describen las zonas de cría y se discute la eficacia de las actuales medidas de ordenación.

1 INTRODUCTION

Shark Bay is situated on the central western coast of Western Australia between latitudes 24°30' and 26°45' S, and longitudes 113°00' and 114°20' E (Fig. 1). It is approximately 130 mi long and 60 mi across at its widest. Water depths are mostly less than 10 fm (18 m) and extensive shallows border the shores (Fig. 2).

Commercial prawn species were first recorded from Shark Bay in 1904, when a sailing trawler, the RIP, was chartered to explore this and other areas on the Western Australian continental shelf (Oxley, 1905). Further exploratory fishing was carried out jointly from 1952 to 1962 by the Western Australian Fisheries Department and the Commonwealth Scientific and Industrial Research Organization's Division of Fisheries and Oceanography (Slack-Smith and Stark, MS). This survey proved the presence of prawns in commercial quantities in Shark Bay. Intermittent fishing by vessels from Geraldton and Fremantle began in 1957, but prawning on a sound commercial basis did not commence until 1962.

When commercial fishing started, estimates of the potential production of this resource were not available, nor were any data available on its possible resilience to heavy exploitation. To protect the population until the nature of these unknown factors could be determined, the Western Australian Government arbitarily limited the number of trawlers to fish in the Shark Bay area to 25 in 1963 (Slack-Smith, 1963). This number was increased to 30 in 1964. In addition, certain areas (Fig. 2) known to contain large numbers of juvenile prawns throughout the year were closed to all trawling. Two fishing companies were encouraged to establish permanent processing and handling facilities in the area by assigning them 60 percent of the total licenses. This encouragement to industry was a necessary step in the development of a sound prawn industry, as Western Australian companies had no previous experience in prawn fishing. This policy of license limitation, desirable during the early development period, has recently been changed to allow free access to all fishing grounds north of Exmouth Gulf.

In view of the extant limit on fishing effort in Shark Bay, research has been carried out to determine at what level fishing intensity should be maintained to ensure rational exploitation. In addition, specific information on prawn population parameters, such as growth, migration, and natural mortality, were required to determine what procedures were necessary to rationalize other penaeid fisheries on the Western Australian coast. To this end the Shark Bay investigation was expanded to include general penaeid fishery dynamics and the relevant biology, as well as the provision of solutions to its own management problems.

2 FISHERY DATA COLLECTION

Western Australia legislation requires all fishermen to submit information on their catch, where it was taken (within a 1° lat by 1° long grid), and the number of fishing operations carried out for each month throughout the year. These returns, originally designed for more extensive oceanic fisheries, do not provide sufficiently detailed catch and effort data to allow comprehensive assessment of the Shark Bay fishery. Special log books were designed and issued to fishermen to collect this more detailed information. These books provide a shot by shot record; the position of each shot of the net is referred to a numbered grid ("block") of 10 by 10 mi. The whole Bay is divided with such squares (Fig. 2). Coded details of the design, mesh size and headrope length are recorded, as well as whether single or double rig gear is used. Slack-Smith and Stark (in press) give further details of the collection and preparation of these data for computer analysis.

Processors purchase approximately 60 percent of all prawns caught. The weighing and recording of the catch of each species landed are therefore accurate. Vessels processing at sea weigh their catch for each trip when it is landed and sent to southern markets by refrigerated road transport. Both sets of data are made available to the Department and the figures are used to adjust fishermen's log book records, which are largely estimated.

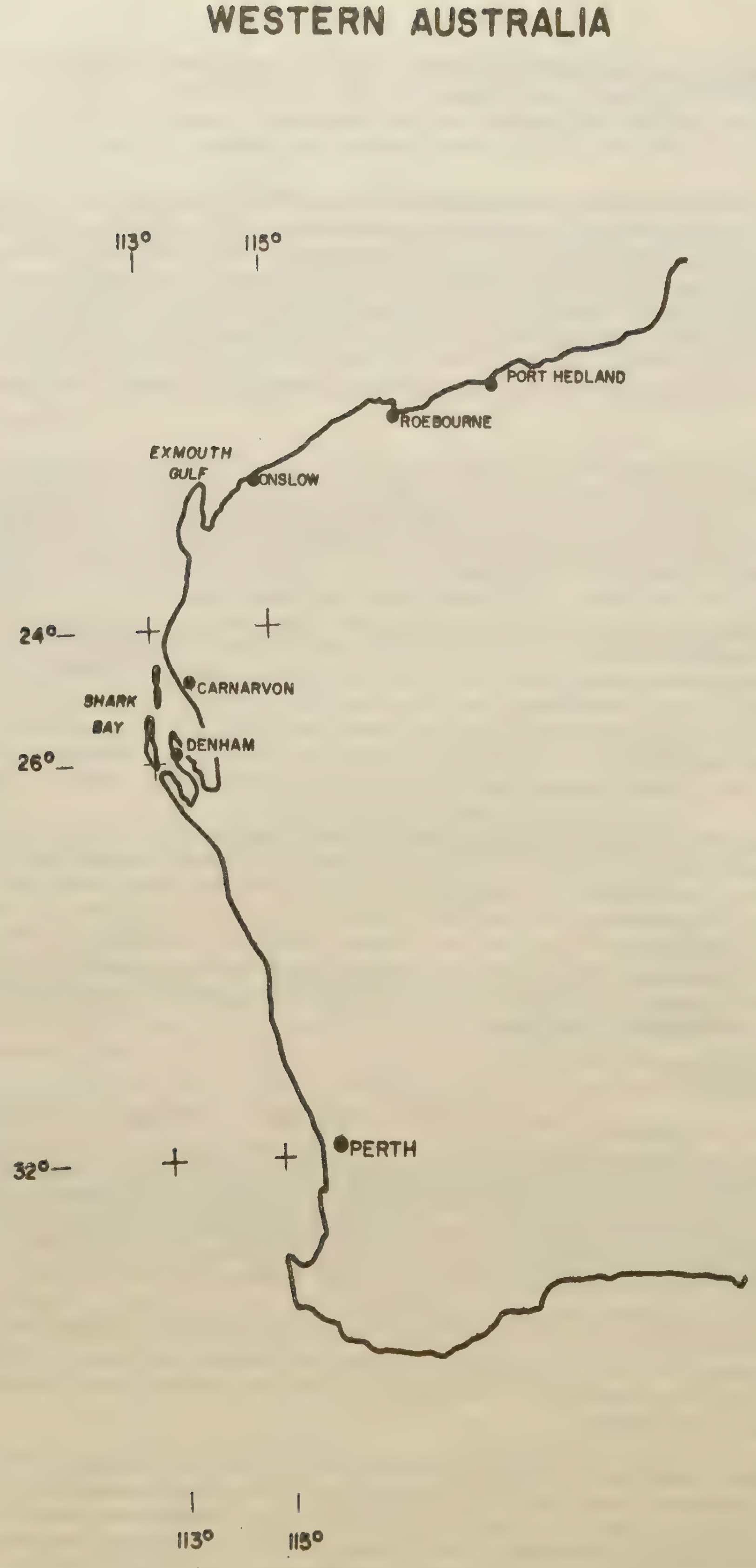
WESTERN AUSTRALIA
113°
115°
PORT HEDLAND
ROEBOURNE
EXMOUTH GULF
ONSLOW
24°
CARNARVON
SHARK BAY
DENHAM
26°
PERTH
32°
113°
115°

Fig. 1 The Western Australian coast showing the position of Shark Bay.

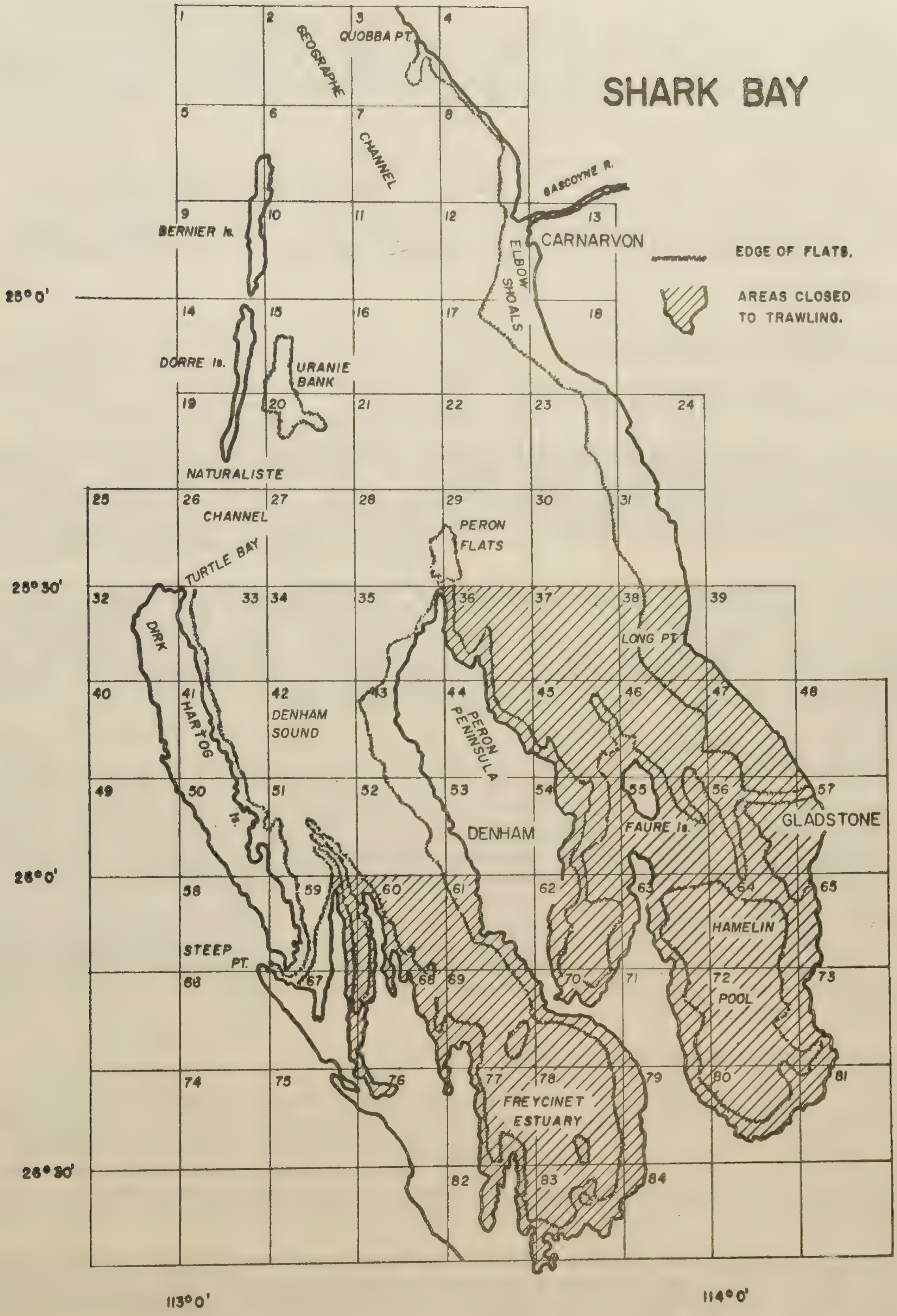
SHARK BAY
QUOBBA PT.
GEOGRAPHE
CHANNEL
GASCOYNE R.
CARNARVON
ELBOW SHOALS
BERNIER Is.
DORRE Is.
URANIE BANK
NATURALISTE
CHANNEL
PERON FLATS
TURTLE BAY
DIRK
HARTOG
Is.
DENHAM SOUND
PERON PENINSULA
LONG PT.
FAURE Is.
GLADSTONE
DENHAM
HAMELIN
POOL
STEEP PT.
FREYCINET ESTUARY
EDGE OF FLATS.
AREAS CLOSED TO TRAWLING.
25°0'
25°30'
26°0'
26°30'
113°0'
114°0'
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Fig. 2 Chart of Shark Bay showing localities mentioned in the text and the numbering of the blocks used for positioning fishing areas. The portions of the bay closed to trawling are also shown.

Processors head and grade the prawns prior to packing and snap freezing into export packs. Grading is on the basis of the number of tails per lb, and the following categories are used: less than 10, 11 to 15, 16 to 20, 21 to 25, 26 to 30, 30 to 40 and greater than 40 tails per lb. The weight of product in each grade is provided by the processors.

During each week, at least one random sample of prawns caught from each block fished is measured to give the size composition of the catch from that area. Each sample consists of between 300 and 400 prawns, and carapace length is measured to the nearest millimeter. In addition, the sex of each prawn is recorded, together with information on the softness of the shell, i.e. whether the prawn has recently moulted.

3 THE FISHING FLEET

3.1 The vessels and gear

The vessels comprising the prawn fleet vary considerably in size and construction. They may be classified as follows:-

3.1.1 Vessels constructed specifically for trawling To date six steel vessels have been built in Western Australia and used in the Shark Bay fishery. These are approximately 50 ft (15 m) overall length. Several wooden trawlers from Queensland fished under charter to a local company between 1962 and 1965, but all except two have now returned to that State. All were under the command of experienced prawn trawlermen.

3.1.2 Vessels used for both the crayfishery and the prawn fishery These form the major group. They range from 42 to 70 ft (13 to 21 m) overall and vary considerably in construction and deck layout. During their first season, this group performed rather poorly when compared with vessels constructed for prawning. This was probably due more to the inexperience of the skippers and crew, rather than vessel design, as the efficiency of the two groups did not vary greatly in the second season.

3.1.3 Trawling gear Flat trawls of several designs are most commonly used in the Shark Bay fishery, although some skippers occasionally use a net of semi-balloon design. Trawl head-ropes vary from 54 to 96 ft (16 to 29 m), depending upon the size and power of the trawler; 75 ft (23 m) nets are the most common. Most trawls are constructed from synthetic fibre. The mesh sizes are 2 in (51 mm) in the body and wings of the net, and 1.75 in (44 mm) in the cod-end. Otter boards are usually 7 ft x 3 ft 6 in (2.1 x 1.0 m), constructed from hardwood and bound with mild steel.

4 THE SHARK BAY ENVIRONMENT

Logan (MS) has provided the only record of the Shark Bay marine environment. Considerable research, most of it not yet published, has been carried out since that time (Logan, personal communication).

4.1 The physico-chemical environment

4.1.1 Water temperatures The winter to summer range is approximately 16° to 27°C in deeper water and channels, whilst that on the shallow flats is approximately 14° to 32°C. During summer, there is a gradient of increasing temperatures from the open sea to the shallow embayments of the south. This gradient is reversed in winter. Stratification seldom occurs, as strong tidal flows and wind turbulence admix the surface and bottom waters.

4.1.2 Salinity Low rainfall (9.0 in (229 mm) per annum) and the mean evaporation rate of 86 in (2,184 mm) per annum maintain hypersaline conditions in all enclosed areas. Salinities ranging from 67°/oo in Hamelin Pool to oceanic conditions (35°/oo) in the vicinity of Naturaliste and Georgraphe Channels have been recorded.

4.2 Tides and currents

Tides are semi-diurnal and range from 4 ft (1.2 m) at spring tide to 1.9 ft (0.58 m) at neaps. Current velocities as high as 3 kn (5.6 km/h) are generated in some channels and velocities of 1.5 kn (2.8 km/h) are common on the trawling grounds. Meteorological and barometric conditions have marked effects on tidal phase and amplitude.

4.3 Sea and weather conditions

Steep, high seas, to 10 ft (3 m) high, are generated by the prevailing east to southwest winds. Most of the Bay is protected from oceanic swell by islands and peninsulas.

Fresh to gale-force southeast to southwest winds prevail in the summer, but in the winter they veer to the east and lose intensity. Occasional summer cyclones occur and attendant winds often reach 120 kn (222 km/h).

4.4 Sediment types and their distribution

Shark Bay sediments are mainly of organic origin, consisting mainly of molluscan and foramenifera shells (Fig. 3). Logan (MS) suggests that the rate of formation of finer sediments is very slow. This seems to imply that, if the bottom were disturbed by some means, whether artificial or natural, a considerable period would elapse before the sediment balance was re-established.

Logan (personal communication) has produced evidence that oceanic water enters Shark Bay through the Naturaliste Channel and then flows north and east through the bay. The magnitude of the eastern component of this flow varies from year to year. The distance that it penetrates toward Cape Peron and the eastern shore is controlled by a dynamic balance between it and high density water flowing northwards from the Hamelin Pool - Faure Island area. Logan has evidence that oceanic water does not reach the area south of Elbow Shoals in some years.

5 THE FISHERY

5.1 Species present

Penaeus latisulcatus Kishinouye (western king prawn) and *P. esculentus* Haswell (tiger prawn) are both fished commerically in Shark Bay. Several other small, non-commercial panaeids are taken in small quantities but not retained. These include *Metapenaeus endeavouri* (Schmitt), *M. dalli* Racek, *Metapenaeopsis novaeguineae* (Haswell), *Trachypenaeus anchoralis* (Bate), *Penaeus monodon* Fabricius, *P. longistylus*, and several species yet to be identified.

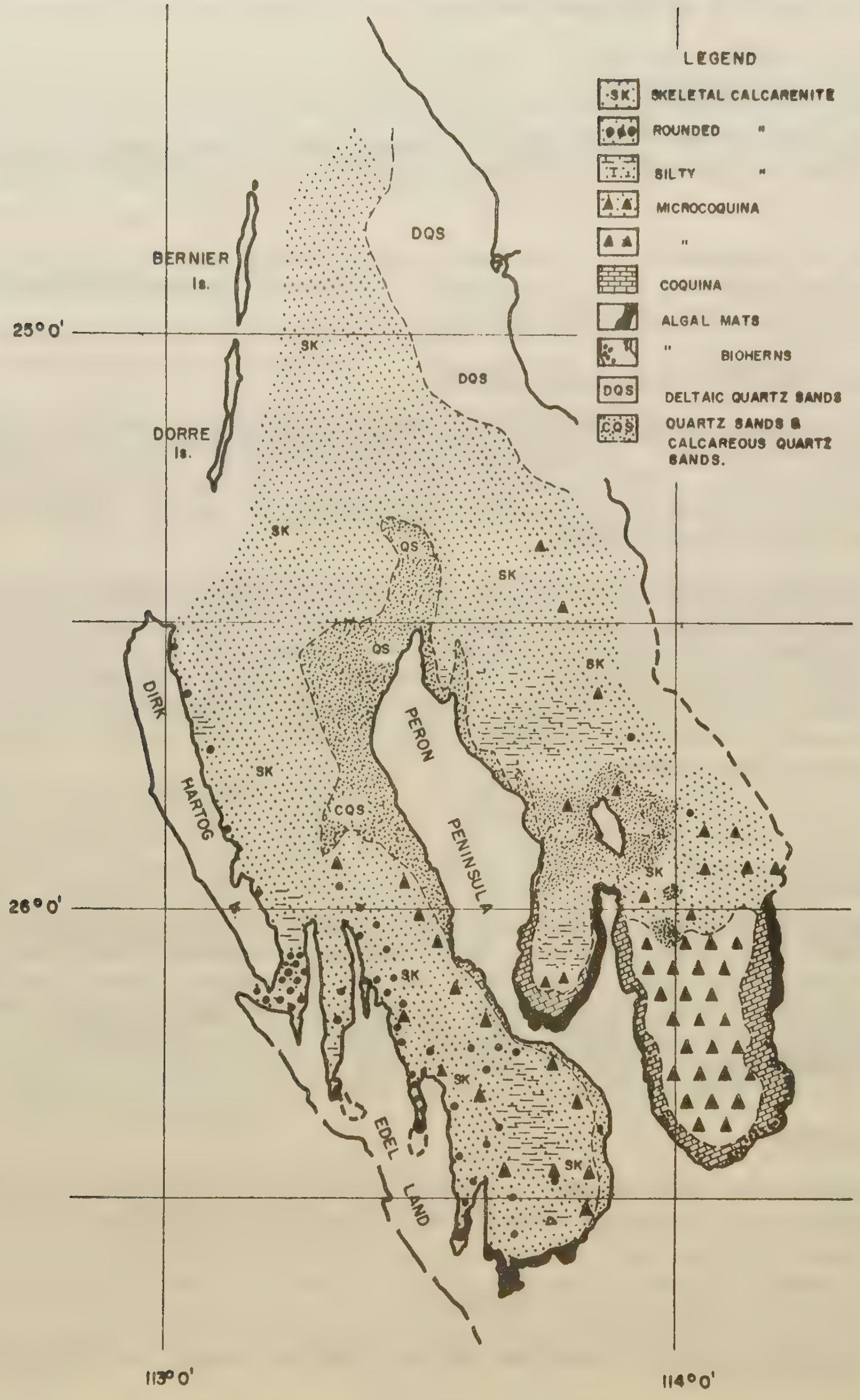
5.2 Fishing seasons

Fishing is carried out from autumn to spring, but the dates of starting and finishing vary from year to year, depending upon weather conditions and the availability of prawns.

TABLE I

Dates of commencement and finishing of the fishing season in Shark Bay

1962	from May 1	to September 15	1965	from March 15	to September 15
1963	April 15	August 30	1966	March 21	September 7
1964	March 15	August 7	1967	March 7	-


LEGEND
SK SKELETAL CALCARENITE
ROUNDED "
SILTY "
MICROCOQUINA
"
COQUINA
ALGAL MATS
" BIOHERNS
DQS DELTAIC QUARTZ SANDS
CQS QUARTZ SANDS & CALCAREOUS QUARTZ SANDS.
BERNIER Is.
DORRE Is.
DQS
DQS
SK
SK
SK
QS
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CQS
SK
SK
SK
SK
SK
DIRK HARTOG
PERON PENINSULA
EDEL LAND
25°0'
26°0'
113°0'
114°0'

Fig. 3 Chart of Shark Bay showing the bottom sediment distribution (after Logan, MS).

5.3 Areas fished within Shark Bay

During 1962, 1963 and 1964 the majority of prawns of both species were caught in the vicinity of Cape Peron on blocks 22 and 29 (Fig. 2). During 1963 and 1964 the fishery expanded, and some trawling was carried out on blocks 3, 7, 11, 12, 16, 17, 21, 28, 30, 42 and 51. Prior to the 1965 fishing season, trawling commenced on the southern blocks 22 and 29, and when there was a falling-off of catches in early July the trawlers gradually moved northwards; in late July, large catches, almost entirely of tiger prawns, were taken in the northern bay (blocks 3 and 7).

However, at the beginning of the 1965 season, prawn numbers were found to be low in all southern areas, but very good catches were taken on blocks 3, 6 and 7. Abundance rose in the southern bay during May but dropped again in mid-June. Fishing was then confined to blocks 11, 12, 16 (the mid bay) and 42 and 51 (Denham Sound) until fishing ceased. A similar pattern occurred in 1966.

5.4 Catch and effort

The relative fishing power of prawn trawlers varies considerably, hence, before estimates of total effective fishing effort generated by a number of different trawlers can be determined, these differences in efficiency need to be eliminated or corrected. Gulland's (1956) method of calculating and applying relative fishing power (RFP) was modified and used on the Shark Bay effort data. This method converts fishing effort from any given vessel in the fleet to the same units as that of a standard vessel or group of vessels.

Changes in RFP were observed to be largely due to variations in fishing skill rather than to differences in the physical characteristics of vessels, e.g. overall length and horsepower (Fig. 4 and 5).

Further difficulties in computing total effective effort ($\hat{g}_e$) for the Shark Bay prawn fishery arise from the presence of two species in the catch. In some cases (e.g. on block 29) both species are caught; in other cases fishing is selective for one species, e.g. tiger prawns are caught almost exclusively on blocks 3 and 7. Even on the same grounds, some vessels show greater selection for a particular species than other vessels fishing beside them. This selection is reflected in the computed relative fishing power values. As it is extremely difficult to divide accurately effort between the two species, it is assumed that vessels fish randomly with respect to king and tiger prawns and that selection is entirely reflected in the RFP values. The effective effort values given (Tables II and III) are based on this assumption.

The general features of the fishery since its establishment in 1962 are described by the catch (C), effort ($\hat{g}$) and catch per unit of effort ($C/\hat{g}$) (Tables II and III). King prawn abundance, as measured by catch per unit of effort, has declined since 1962, particularly from 1965 onwards. Total catch fell in these latter years in spite of increased fishing effort.

Tiger prawn catches, on the other hand, have increased throughout the period of the fishery, although catch per unit of effort has dropped.

6 SIZE AND COMPOSITION OF THE CATCH

6.1 Variation of size associated with sex

In a given sample, king prawn females from 23 mm carapace length (C.L.) upwards are noticeably larger than males. A similar size difference for tiger prawns, commencing at 22 mm C.L., is also noted. The increasing spread of values within female size composition modal groups (Fig. 6) suggests that the growth rate of males has decreased. In both species this differentiation coincides with commencement of gonad development.

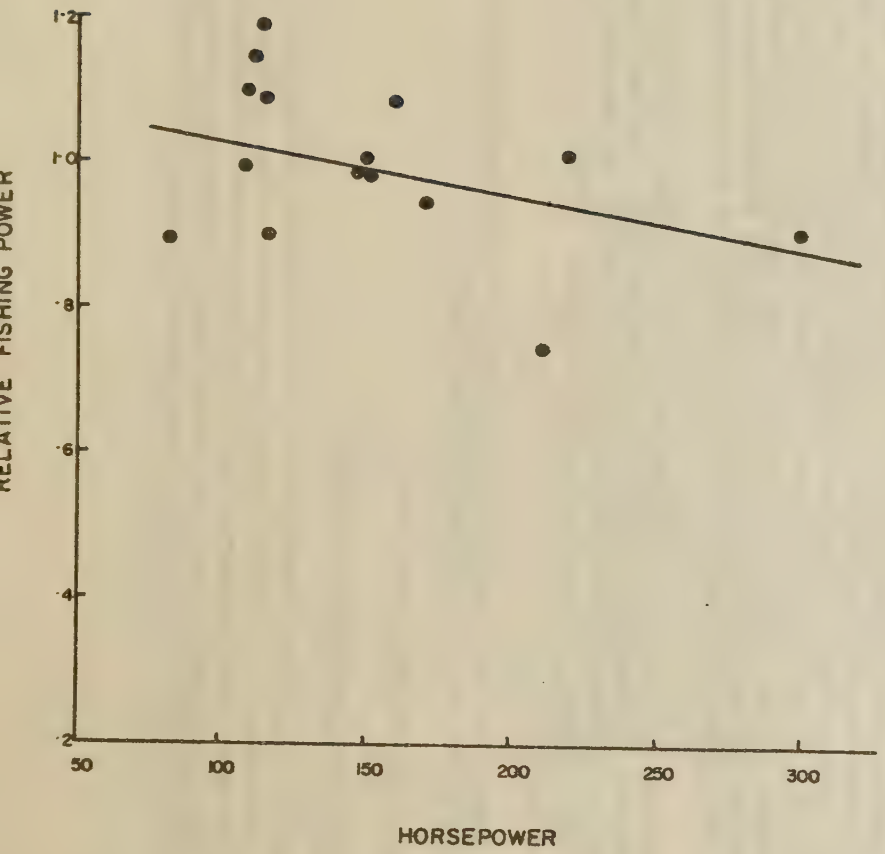

Fig. 4 Relative fishing powers of Shark Bay prawn trawlers plotted against their rated horsepowers.

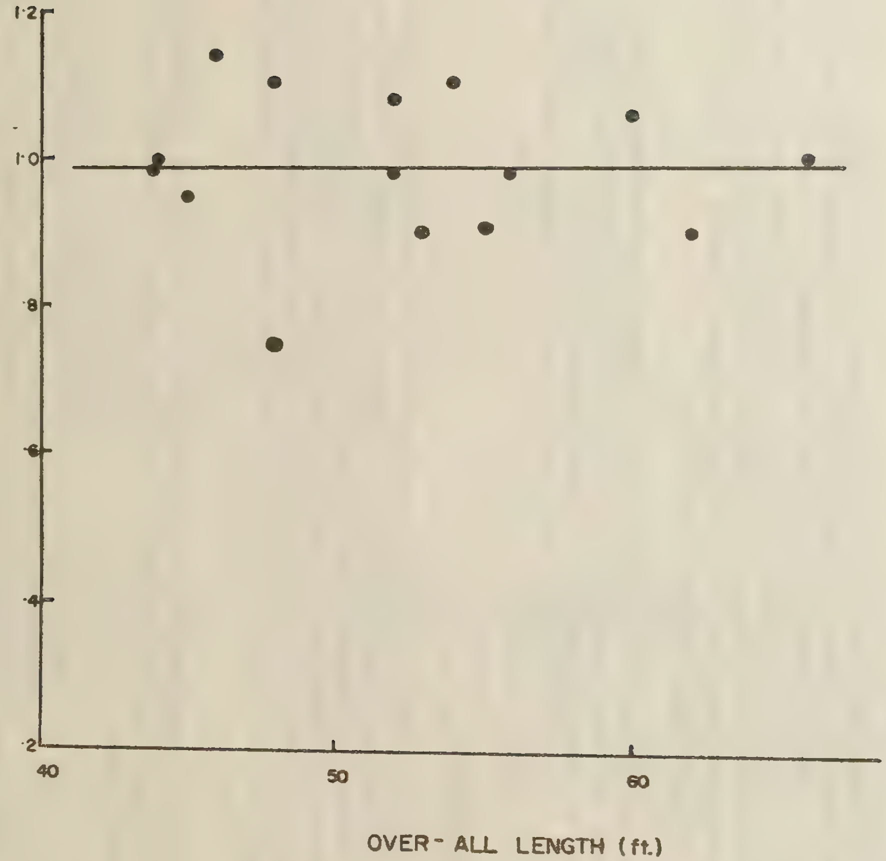

Fig. 5 Relative fishing powers of Shark Bay prawn trawlers plotted against their overall lengths.

TABLE II

Catch (C) in pounds and effort ($\hat{g}$) in standard vessel hours fished for king prawns (*Penaeus latisulcatus*) caught in the Shark Bay fishery from 1962 to 1966

Year	1962			1963 1/			1964			1965			1966		
Month	C	$\hat{g}$	C/$\hat{g}$	C	$\hat{g}$	C/$\hat{g}$	C	$\hat{g}$	C/$\hat{g}$	C	$\hat{g}$	C/$\hat{g}$	C	$\hat{g}$	C/$\hat{g}$
March							12,166	228	53.3	1,485	83	17.8	8,938	129	69.2
April				50,136	169.9	295	229,016	2,687	85.2	54,746	2,294	23.9	98,918	3,841	25.1
May	24,944	309	80.7	89,416	239.7	373	316,158	3,707	85,2	214,546	4,044	53.0	162,957	5,077	32.1
June	67,875	944	71.9	149,120	300.6	496	263,433	4,000	65.8	288,606	3,440	83.8	160,027	5,756	27.8
July	81,543	871	93.6	186,218	360.8	516	227,738	4,287	53.1	181,113	3,440	52.6	140,576	6,304	22.3
Aug.	41,030	683	60.0	84,660	190.9	443	17,632	241	73.1	135,887	2,473	54.9	60,899	3,520	17.3
Sept.	3,582	68	51.2							83,574	972	85.9	5,078	278	18.3
TOTAL	218,874	3875	76.1	559,550	1261.9	443	1,066,143	15,150	70.3	959,957	16,746	57.3	637,393	24,905	25.6

1/ Effort is in boat nights for 1963 - log book data was not sufficiently detailed to make accurate estimates of standard vessels hours fished

TABLE III

Catch (C) in pounds and effort ($\hat{g}$) in standard vessel hours fished for tiger prawns (*Penaeus esculentus*) caught in the Shark Bay fishery from 1962 to 1966

Year	1962			1963 1/			1964			1965			1966		
Month	C	$\hat{g}$	C/$\hat{g}$	C	g	C/g	C	$\hat{g}$	C/$\hat{g}$	C	$\hat{g}$	C/$\hat{g}$	C	$\hat{g}$	C/$\hat{g}$
March							9,669	178	54.3	4,621	85	54.3	22,300	119	187.3
April				65,793	169.6	387	157,718	2,194	71.8	83,277	2,361	35.3	188,278	3,676	51.3
May	9,163	234	39.1	173,638	239.7	724	237,060	3,551	66.7	289,924	4,195	69.1	224,684	4,776	47.1
June	44,690	672	66.5	94,592	300.6	315	215,554	3,678	58.6	195,988	3,644	53.7	265,579	5,420	49.0
July	24,995	988	25.2	78,764	360.8	218	199,504	5,939	33.5	139,414	3,591	38.8	141,801	5,718	24.8
August	13,476	815	16.5	55,493	190.9	290	19,729	185	106.6	92,761	2,614	35.5	64,011	3,317	19.5
Sept.	4,128	167	24.7							29,937	825	36.2	7,176	159	45.1
TOTAL	96,452	2,876	33.5	468,280	1261.9	371	829,234	15,725	52.7	844,922	17,315	48.8	913,829	23,185	39.4

1/ Effort is in boat nights for 1963 - log book data was not sufficiently detailed to make accurate estimates of standard vessels hours fished

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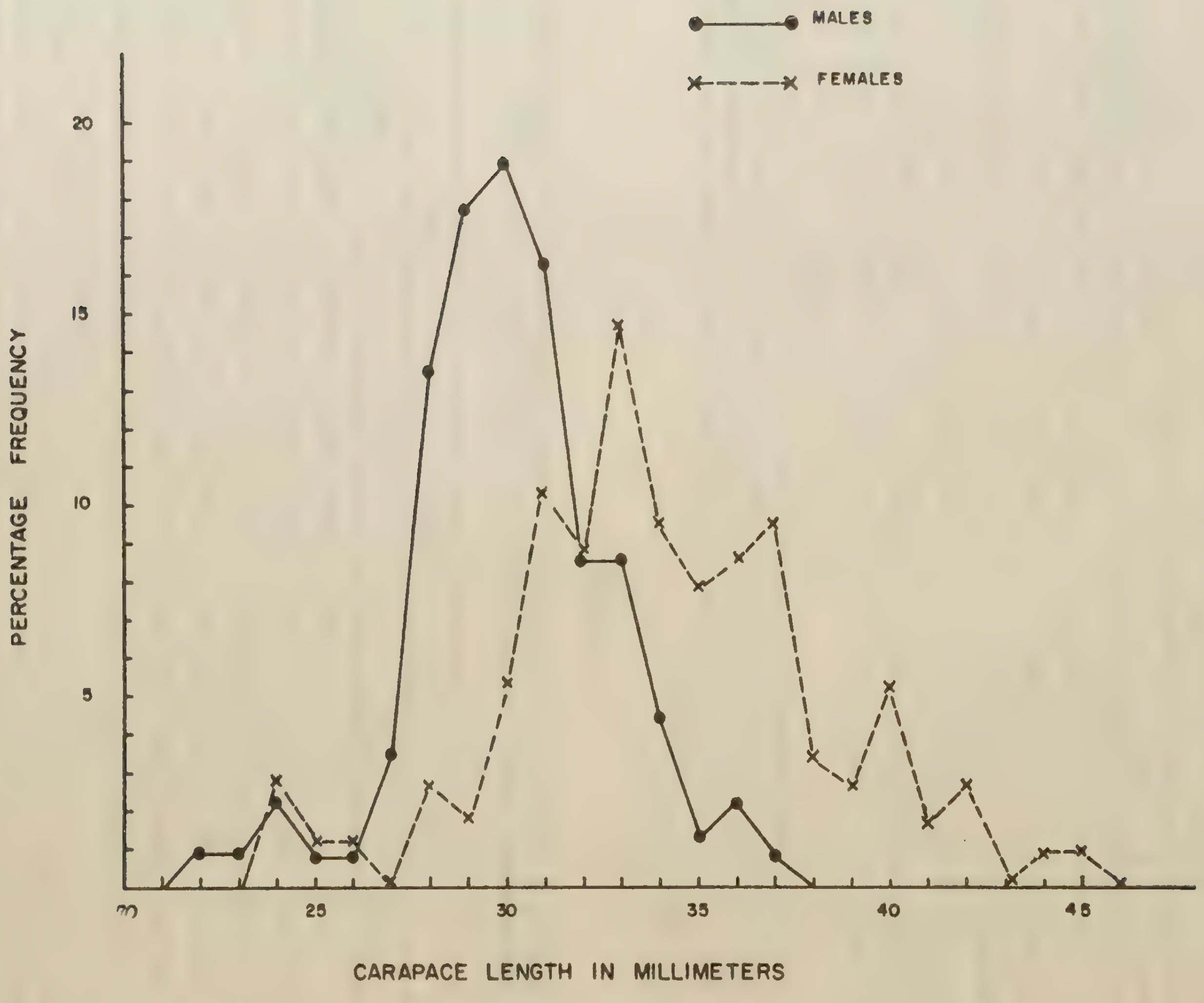

Fig. 6 Percentage frequency distribution of carapace lengths of male and female king prawn (Penaeus latisulcatus). (From commercial catch taken on Block 2 during 10 April 1967).

The sex ratio of king prawns fluctuates from 40.5 to 61.0 percent of females, with a mean ratio of 47.0 percent; tiger prawns vary from 34.6 to 70.0 percent, with a mean of 47.0 percent. However, in most samples the sex ratio falls between 45.0 and 52.0 percent of females.

6.2 Relationship of size composition with factory packing grades

During periods of the season when size-composition sampling is not carried out, it is often possible to examine broad changes in size-composition from the percentage of the landed catch falling into each of the tail-weight grades packed at the processing factories. Experiments to determine the relationship between carapace length and tail weight have been carried out (Tables IV and V).

Some caution is needed in the use of size-composition changes determined in this manner, as they take no cognisance of the sex ratio of the catch.

6.3 Growth and seasonal changes in size composition

The modal size of both king and tiger prawns on a particular block has been observed to increase as the fishing season progresses. If the size-composition of prawns on a number of blocks at a given time is examined, the modal size increases from south to north. Results from dye marking experiments have shown that south-to-north migration of both species occurs. Hence, any changes in size composition observed either in time or from different geographic locations contain elements of both growth and migration. Growth rate studies using progression of modes have not been possible due to the presence of this migration component in any changes in modal size.

It is therefore necessary to make a detailed study of all available data, so that the contribution of all the above factors to changes in size composition may be determined. To this end, the numbers caught in each mm carapace-length size-group, on each block fished, during each week of the season, have been computed for both sexes of each species. These data form the basis of a fishery model used to interpret the changes described above (Slack-Smith, in press).

7 PENAEID LIFE CYCLE AND RECRUITMENT

The life cycle of seagoing penaeids in the Gulf of Mexico has been extensively studied by a number of workers (Weymouth, Lindner and Anderson, 1933; Lindner and Anderson, 1956; Williams, 1955; Simmons, 1957; Tabb, Dubrow and Jones, 1962; St.Amant, Broom and Ford, 1966; and others). Dakin (1938), Morris and Bennet (1951) and Racek (1959) have studied the life cycles of several Australian species, particularly Penaeus plebejus. Although the life cycles of the commercial species in Shark Bay have not been studied in detail it is likely that they follow the general pattern observed by these authors.

The Shark Bay prawn nursery areas are extensive (Slack-Smith, 1966) (Fig. 7), although the greatest concentrations of postlarvae and juveniles have been found on the eastern shore between Gladstone and the Gascoyne River. The greatest abundance of both species has been observed in summer.

Data on the duration of the planktonic, nursery area or pre-recruit phases of the penaeid life histories in Shark Bay is not available, but it appears certain that individuals reach sexual maturity within one year after hatching.

Size composition data of the commercial catch shows that recruitment probably occurs throughout the year, with peak recruitment occurring in summer. This latter recruitment provides the bulk of the Shark Bay prawn catch.

Recruitment to the fishery occurs in waves. The waves are probably related to lunar periodicity in spawning and subsequent migration from the nursery areas.

TABLE IV

Mean tail and total weight in g for king prawns (Penaeus latisulcatus) in given carapace lengths. Recovery rates and carapace length-total weight relationships are also given

Carapace Length (mm)	MALE No.	MALE Mean Total Wt(g)	MALE Mean Tail Wt(g)	MALE Recovery Rate (%)	FEMALE No.	FEMALE Mean Total Wt(g)	FEMALE Mean Tail Wt(g)	FEMALE Recovery Rate (%)
26	1							
27	2	10.55	7.09	66.7				
28	5	14.18	8.51	60.0	3	14.18	7.09	50.0
29	16	15.51	9.30	60.0	3	14.18	7.09	50.0
30	31	16.70	10.29	61.6	4	17.72	8.87	50.1
31	37	18.57	11.48	61.8	8	17.72	10.63	60.0
32	42	20.07	12.47	62.1	17	20.44	12.11	59.2
33	63	22.06	12.70	62.7	35	21.46	13.78	64.2
34	69	23.84	14.88	62.4	38	24.10	14.54	60.4
35	58	26.39	16.61	62.9	48	25.54	15.65	61.3
36	36	27.75	17.12	61.7	42	28.35	17.38	61.3
37	11	30.28	18.68	61.7	46	30.19	18.34	60.8
38	4	33.68	19.50	75.9	34	32.09	19.39	60.4
39	2	31.89	21.26	66.7	29	33.18	20.78	59.1
40					25	36.86	21.55	58.4
41					8	39.86	23.05	57.8
42					13	40.88	24.52	60.0
43					12	44.31	26.59	60.0
44					2	46.01	28.35	61.5
45								
46								
47								
TOTALS	377				372			

Recovery Rate - Female - 60.2%
Male - 62.2%
Combined - 61.1%

Length-Weight Relationships

Male - Total weight = 0.252 x $(C.L.)^{2.895}$

Female - Total weight = 0.150 x $(C.L.)^{2.677}$

TABLE V

Mean tail and total weights in g for tiger prawns (Penaeus esculentus) in given carapace lengths. Recovery rates and carapace length-total weight relationships are also given

Carapace Length (mm)	MALE No.	MALE Mean Total Wt(g)	MALE Mean Tail Wt(g)	MALE Recovery Rate (%)	FEMALE No.	FEMALE Mean Total Wt(g)	FEMALE Mean Tail Wt(g)	FEMALE Recovery Rate (%)
26	3	18.91	9.44	50				
27	15	19.85	15.11	76				
28	34	20.02	16.67	83				
29	84	22.96	16.19	71	14	24.30	16.19	67
30	80	25.52	18.43	72	10	34.02	22.68	67
31	69	27.95	18.09	65	34	30.02	16.67	56
32	33	27.50	20.61	75	53	30.00	21.40	71
33	17	33.34	23.36	70	50	32.89	22.68	69
34	17	33.34	26.68	80	50	34.02	24.95	73
35	5	45.36	28.35	63	35	38.87	25.91	67
36					21	43.21	29.71	69
37					10	45.36	34.02	75
38					13	52.33	43.60	83
39					12	56.70	37.79	67
40					8	56.70	42.53	75
41					4	56.70	49.61	88
42					9	62.99	37.79	60
43					3	75.61	56.70	75
44								
TOTALS	357				329			

Recovery Rate - Female - 69.7%
Male - 71.0%
Combined 70.3%

Length-Weight Relationships

Male Total Wt. = 0.0961 x $(C.L.)^{2.471}$

Female Total Wt. = 0.488 x $(C.L.)^{2.197}$

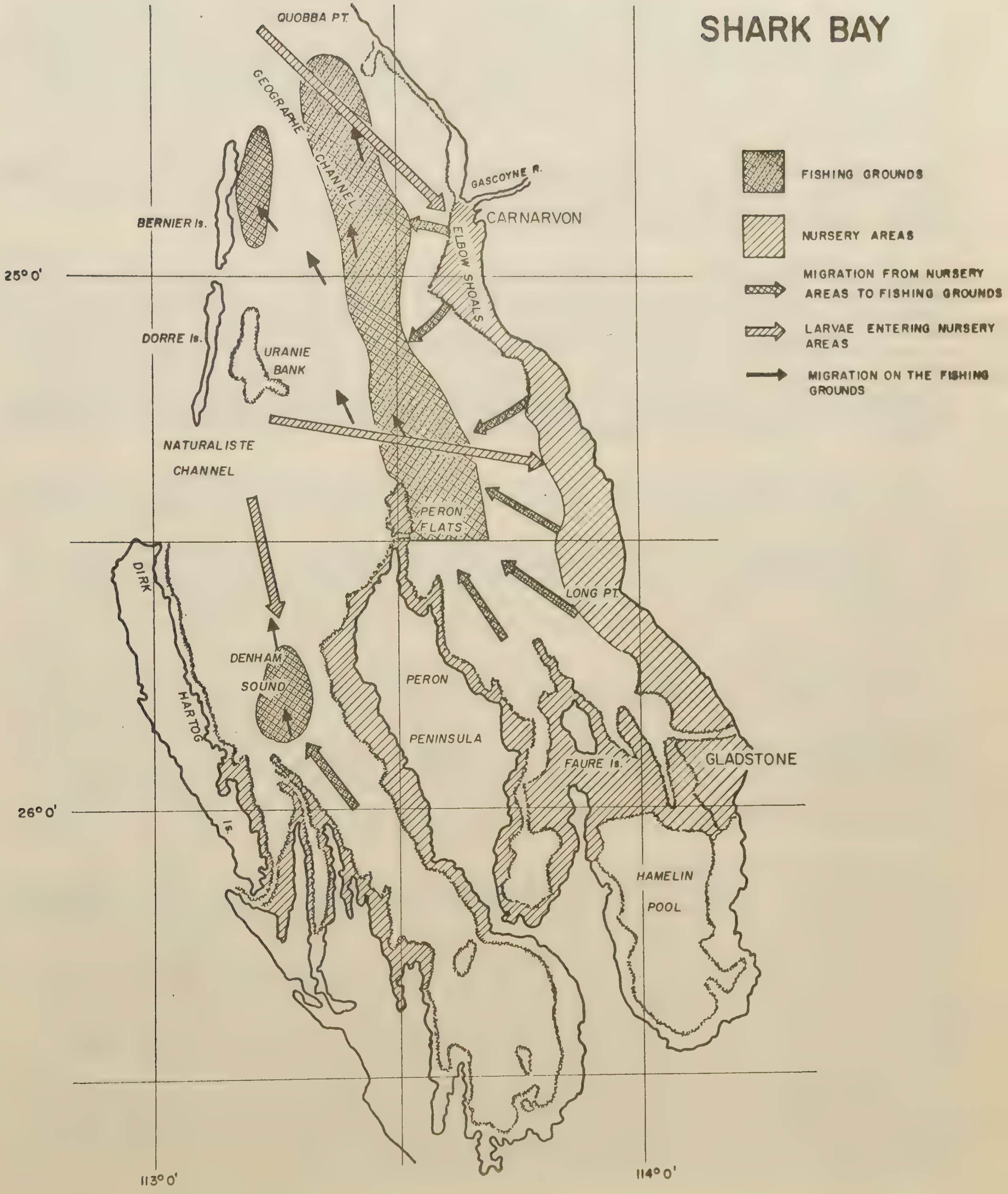
SHARK BAY
FISHING GROUNDS
NURSERY AREAS
MIGRATION FROM NURSERY AREAS TO FISHING GROUNDS
LARVAE ENTERING NURSERY AREAS
MIGRATION ON THE FISHING GROUNDS
QUOBBA PT.
GEOGRAPHE CHANNEL
GASCOYNE R.
CARNARVON
BERNIER Is.
ELBOW SHOALS
25° 0'
DORRE Is.
URANIE BANK
NATURALISTE CHANNEL
PERON FLATS
LONG PT.
DIRK
HARTOG
Is.
DENHAM SOUND
PERON
PENINSULA
FAURE Is.
GLADSTONE
26° 0'
HAMELIN
POOL
113° 0'
114° 0'

Fig. 7 The generalized pattern of prawn migration in Shark Bay. Fishing areas are also shown.

8 DISCUSSION

The basic aim of any research orientated towards fishery management is to provide administration and industry with information on which to regulate the fishery, so that the fishery persists and maximum catches are taken. In most fisheries it is sufficient to study growth, mortalities and exploitation rate and to express yield as yield per recruit (Y/R). Although recruitment often varies, the presence of a number of age-classes in the stock usually dampens any violent effects these may have on catch.

Penaeid fisheries are usually on one-year stocks and consequently violent fluctuations in recruitment are followed by similar fluctuations in catch. The pre-requisite for management of a prawn fishery is the knowledge of whether these fluctuations are random, cyclic or generally trending downwards. Random and cyclic changes are not usually related to the effects of fishing.

The decline in mean annual density ($C/\hat{g}$) observed in the Shark Bay fishery has not been observed for a sufficient period to determine whether it is only random or cyclic. However, if these changes are examined in relation to the areas fished (Section 5.3) it appears that recruitment of both king and tiger prawns to the southern grounds has decreased markedly from 1965 onwards. As penaeid fecundity is extremely high (Ingle, 1961; Joyce and Eldred, 1966) it seems unlikely that fishing has affected the production of potential recruits. This suggests that changes in the environment in the area should be examined in relation to the decline in recruitment. Two hypotheses based on changes in the physical environment are postulated.

The first is that intensive trawling in the southern bay during 1962 to 1964 has caused deleterious changes in the habitat. The otter boards and footropes of trawl nets stirred up the fine sediment and brought it into suspension. These were then carried away by the strong tidal and current flow (Sections 4.4 and 4.5). Under natural conditions, drifting fine sediment was probably largely trapped by patches of sea grass, but much of this weed has also been destroyed by trawling. This destruction of suitable prawn habitat would decrease the numbers available to be caught by either increasing the rate of natural mortality or the rate of migration on the affected grounds.

The second hypothesis is that changes in the pattern of water circulation (Section 4.5) have decreased the numbers of postlarvae reaching the nursery areas south of Elbow Shoals (Fig. 2). The southern areas were the major king prawn nurseries, whereas the areas to the north comprised the major tiger prawn nurseries. Thus, if lodgment of both species was decreased on the southern nursery areas during 1965 to 1966, the observed distribution of densities (C/g) and catches of both species during these seasons would follow. An observation by Logan (personal communication) that the eastern tongue of water entering Shark Bay (Section 4.5) did not reach the area south of Elbow Shoals during 1965 to 1966 adds weight to the second hypothesis.

If the first hypothesis proves correct, and if sediment regeneration in disturbed areas is extremely slow, the life of the fishery is probably limited. In such circumstances management measures should be directed toward prolonging its life by making the maximum of catch with the minimum of habitat damage. If sediment regeneration is relatively fast, the regulation of fishing effort and of areas fished should be instituded, so that habitat damage is not allowed to become substantial in any particular area. In both cases, the most efficient method of exploiting the resource is to ensure that the M/K ratio (Holt, 1962) of the fishable stock and the relative fishing power (i.e. catchability) of the trawlers are maximised. In the latter case, limitation of fishing effort could be obtained by license limitation.

However, if the hypothesis is true that the fluctuations observed in the Shark Bay fishery are caused only by changes in the current patterns within the Bay, it is not necessary to limit fishing effort to ensure that the population is maintained, and research should be orientated towards maximising M/K.

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THE PRAWN FISHERY RESOURCES OF INDIA

by

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Abstract

The growth of the prawn fishing industry in India in recent years is reviewed and the increasing value of prawn exports is tabulated. The most important fishery is for various penaeid species on the west coast.

The commercially important species on all Indian coasts are listed, the geographical areas in which they are fished are defined, and notes are given on the maximum size attained by the species, the depths in which they are fished and the nets and boats used. More extensive culturing of prawns is recommended.

Indian prawn stocks are, in general, not overfished, and the fishing effort can be safely increased.

LES RESSOURCES CREVÈTTIERES DE L'INDE

Résumé

La communication étudie le développement de la pêche de la crevette en Inde ces dernières années, et illustre par des tableaux la valeur croissante des exportations de ce produit. L'exploitation porte surtout sur divers Pénéidés de la côte occidentale.

L'auteur énumère les espèces d'importance commerciale de toutes les côtes indiennes, définit les zones de pêche, et fournit des indications sur la taille maximale des diverses espèces, les profondeurs auxquelles elles sont récoltées, et les filets et bateaux employés. Il préconise une expansion de l'élevage des crevettes.

Dans l'ensemble, les stocks indiens de crevettes ne sont pas surexploités, et l'effort de pêche peut être accru sans danger.

E/35

LOS RECURSOS DE LA PESQUERIA DE LANGOSTINOS DE LA INDIA

Extracto

Se examina el crecimiento de la industria pesquera de camarones en la India durante estos años, y se presentan tabulados datos del creciente valor de las exportaciones de camarones. La pesquería más importante es la de varias especies de peneidos en la costa occidental.

Se indican las especies comercialmente importantes en todas las costas de la India, se definen las zonas geográficas en las que se pescan, y se dan notas sobre la talla máxima que obtienen las especies, las profundidades a las que se pescan y las redes y embarcaciones empleadas. Se recomienda un cultivo más extensivo de los camarones.

En general, las poblaciones de camarones indios no se pescan excesivamente, pudiéndose aumentar sin peligro el esfuerzo pesquero.

1 INTRODUCTION

Prawns in general form the most economically important constituent in the marine fish landings in India, accounting for an average of over 75,000 metric tons which comes to about 10 per cent of the total landings of marine species. In addition, substantial quantities of prawns of marine origin, amounting to about a third of the above, are caught from the various estuaries, tidal creeks, brackish water lakes and backwaters along the coast. The annual production of marine prawns in the country could therefore be reasonably estimated at about 100,000 tons a year. The typical freshwater species form only a sustenance fishery of minor importance, except in a few isolated areas where some of the large palaemonids form fisheries of local importance.

The prawn industry in the country maintained the age old pattern till the beginning of the fifties of this century, supporting an export trade of dried and semi-dried prawns worth a few million rupees at the most. However, rapid and phenomenal transformation has taken place within the last 15 years raising it to the status of an organized industry of considerable importance. All other fisheries are relegated to the background, and a most modern and sophisticated industry of frozen and canned prawns has sprung up, with an export record of over 100 million rupees by 1966 (Table I). These phenomenal changes have raised India to the status of one of the foremost prawn exporting countries in the world. The export figures for prawns and prawn products from the country in recent years are given in Table II.

A combination of favourable factors has contributed to the progressive transformation that has taken place in the industry. The main factor was the steadily increasing demand for frozen and canned shrimps in the western countries, especially in the U.S.A., which led to the exploration and organization of new sources of supply by those interested in the trade. In the meanwhile, governmental activities, including exploratory fishing and research on prawns, mechanization of fishing craft, provision of ice-plant and cold storage facilities, increased attention to the socio-economic conditions of the fishing community, and export promotion incentives created a suitable climate for organizing the industry on modern lines. This encouraged the industrialists, especially of the southern section of the west coast of India, who were the pioneers in the field and whose initiative and enterprise deserve special mention.

2 PRAWN CATCHES

Information on the prawn fisheries of India and on the biology of the economically important species is available in a number of contributions from this Institute, of which the most important ones of a general nature are those by Panikkar and Menon (1956), Jones (1967) and Mohamed (1967). Further, synopses on all the important marine prawns are being presented at this meeting by members of this Institute, and other contributions relate to the biology and fishery of Indian prawns. Only a brief account is therefore attempted here.

The prawn production in the country is given in Table III.

About 80 percent of the marine prawn catches come from the west coast of India, while the east coast accounts for about 20 percent. Along the west coast, the catches are higher in the northern sector, but the southern sector supports the fishery for the larger species, resulting in a concentration of prawn processing industry in this area.

The economically important prawns constituting the major portion of the catches are the penaeids belonging to the genera Penaeus, Metapenaeus, Parapenaeopsis and Solenocera. In addition to the above, non-penaeid species belonging to the genera Palaemon, Hippolysmata, and Acetes are also caught. In some sectors, especially in the northern sections of the east and west coasts, they are available in appreciable quantities and form a major sustenance fishery. However, in view of their comparatively smaller size, they do not attract the freezing and canning industry, and therefore they are commercially much less important than the larger forms.

TABLE I

Export of frozen and canned prawns from India
(1953 - 1966)

Year	Frozen prawns		Canned prawns		Total	
	Quantity (1,000 kg)	Value (1,000 Rs)	Quantity (1,000 kg)	Value (1,000 Rs)	Quantity (1,000 kg)	Value (1,000 Rs)
1953	13	58	-	-	13	58
1954	61	273	-	-	61	273
1955	48	294	-	-	48	294
1956	190	1,097	-	-	190	1,097
1957	496	2,134	-	-	496	2,134
1958	780	3,790	-	-	780	3,790
1959	1,050	4,923	373	2,324	1,422	7,247
1960	1,211	5,866	320	1,784	1,531	7,650
1961	1,463	7,367	622	4,223	2,084	11,590
1962	2,238	1 ,820	970	6,560	3,208	17,380
1963	3,967	21,203	1,231	7,576	5,198	28,779
1964	5,870	31,517	1,074	6,992	6,944	38,509
1965	7,028	41,422	1,148	9,506	8,176	50,928
1966 1/	8,784	88,792	1,523	18,657	10,407	107,448

TABLE II

Export of prawns and prawn products from India
(1960 - 1966)

		1960	1961	1962	1963	1964	1965	1966 1/
1. Frozen Prawns	Q (1,000 kg)	1,211	1,463	2,238	3,967	5,870	7,028	8,784
	V (1,000 Rs)	5,866	7,367	10,820	21,204	31,518	41,422	88,792
2. Canned Prawns	Q (1,000 kg)	320	622	970	1,231	1,074	1,148	1,523
	V (1,000 Rs)	1,784	4,223	6,559	7,576	6,992	9,506	18,657
3. Dried Prawns	Q (1,000 kg)	-	-	-	2,809	3,009	1,702	1,463
	V (1,000 Rs)				9,325	8,997	5,447	5,271
4. Prawn Powder	Q (1,000 kg)	-	-	-	255	511	104	81
	V (1,000 Rs)				84	126	66	53
5. Prawn Pickles	Q (1,000 kg)	-	-	-	-	1	1	2
	V (1,000 Rs)					3	3	12
Total	Q (1,000 kg)	1,531	2,085	3,208	8,261	10,465	9,983	11,853
	V (1,000 Rs)	7,650	11,590	17,379	38,189	47,636	56,444	112,785

Q - Quantity V - Value

1/ The sudden increase in value registered in 1966 is due partly to the devaluation of the Indian Rupee.

TABLE III
Estimated landings of prawns in metric tons (1958 - 1966)

Year	West coast			East coast			Combined total for west and east coasts
	Penaeid prawns	Non-penaeid prawns	Total	Penaeid prawns	Non-penaeid prawns	Total	
1958	26,293	53,501	79,794	2,910	2,485	5,396	85,190
1959	23,548	36,775	60,323	4,084	1,030	5,114	65,437
1960	27,503	35,004	62,507	4,256	1,267	5,523	68,030
1961	32,864	22,018	54,882	6,219	1,667	7,886	62,768
1962	42,227	34,576	76,803	6,023	409	6,432	83,235
1963	30,747	39,554	70,301	10,323	969	11,292	81,593
1964	52,018	30,164	82,182	11,369	1,342	12,711	94,893
1965	29,918	41,003	70,921	8,103	412	8,575	79,496
1966	35,109	33,154	68,263	9,287	1,091	10,378	78,641

As stated already, substantial quantities of prawns of marine origin are caught from the numerous estuaries, creeks, brackish water lakes and backwaters along the coasts of India. Of these, the most important estuaries are the Sundarbans (the Gangetic estuarine system) in West Bengal and Godavary in Andhra Pradesh, each accounting for about 1,000 tons a year. Among the brackish water lakes, the Chilka (in Orissa) and the Pulicat (in the States of Madras and Andhra Pradesh) produce annually about 1,000 tons. The Kolleru (Collair) Lake in Andhra Pradesh is another sustaining a good fishery of both penaeid and non-penaeid prawns. The most important backwater, from the prawn fisheries point of view, is the one in the Cochin area of Kerala, with an estimated annual production of over 10,000 tons.

In the less saline areas and the connected freshwater systems of the Cochin backwaters there is a significant commercial fishery for the giant freshwater prawn Macrobrachium rosenbergii. About 400 tons are caught annually.

3 PRAWNS OF COMMERCIAL IMPORTANCE

Notes on different species contributing to the prawn fisheries of India are given below.

3.1 Penaeids

Though essentially marine, most of the species are able to live in brackish waters of very low salinity. The distribution of the fishery of commercially important prawns of India is given in Fig. 1 to 3.

Penaeus indicus H. Milne Edwards. The species attains a maximum length of 20 to 23 cm. Because it is widely available in the coastal waters, estuaries and backwaters of India, and because it is a relatively large prawn, this is the most important species. The young ones come to the backwaters and estuaries where they grow to about 12 to 13 cm. Breeding takes place in the sea. The species is important in the backwater fisheries and the paddy field prawn fishery of Kerala.

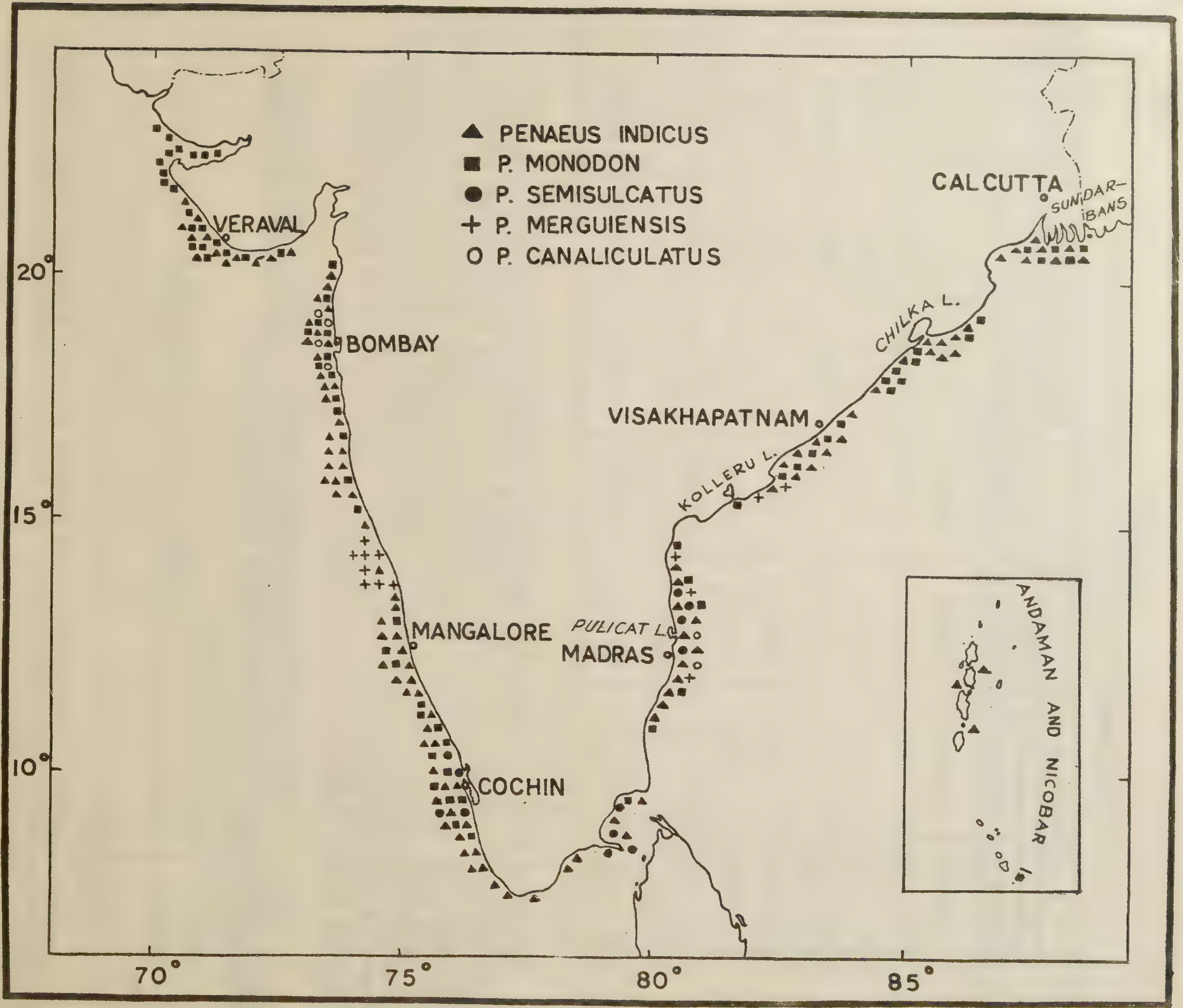
▲ PENAEUS INDICUS
■ P. MONODON
● P. SEMISULCATUS
+ P. MERGUIENSIS
O P. CANALICULATUS
VERAVAL
BOMBAY
MANGALORE
COCHIN
PULICAT L.
MADRAS
KOLLERU L.
VISAKHAPATNAM
CHILKA L.
CALCUTTA
SUNDAR-IBANS
ANDAMAN AND NICOBAR Is.
20°
15°
10°
70°
75°
80°
85°

Fig. 1 Distribution of fishery for Penaeus spp.

P. indicus is caught in various types of seine net operated from indigenous craft in inshore waters and in shrimp trawls operated from powered boats in deeper areas. It is occasionally caught in shore seines. In the backwaters and estuaries, stake nets, dip nets, cast nets and traps are the most important gear employed in the fishery for this species. In the Chilka Lake, large quantities are caught by trapping. In the Kerala backwaters, the picturesque fixed dip nets (cheena-vala) catch appreciable quantities of these prawns along with other species. The same fishing methods apply for all the other species of penaeid prawns. The species is available in the estuaries and backwaters almost throughout the year although the sizes available differ with the season. In the sea, it is commonly fished during the post-monsoon months.

Penaeus monodon Fabricius. This is probably the largest Indian marine prawn, attaining a maximum length of about 30 cm, but it does not form a dominant fishery anywhere. It is more common along the east coast, especially the northern section (Bengal and Orissa) where it is fished mostly in the months following the monsoon. On the west coast, it is caught in very small numbers, mostly in the northern section. As in the previous species, breeding takes place in the sea and the juveniles enter estuaries and lakes.

Penaeus semisulcatus de Haan. This species is also more common on the east coast, although not as important as P. monodon. It grows to nearly the same size. It contributes very little to the fishery on the west coast.

Penaeus merguiensis de Man. Till recently this was considered as a variety of P. indicus, and has been confused with it in several localities. It has now been found to contribute substantially to the commercial fishery along the Karwar coast (north of Mangalore) where it is fished with other species. The maximum length is about 20 cm.

Penaeus canaliculatus Olivier. This prawn makes a small contribution to the fishery along the Madras coast, especially in Pulicat Lake, and occurs in small numbers in Bombay and other places. It attains a maximum size of 12 to 15 cm. Like P. monodon and P. semisulcatus it occurs in the east coast fishery mainly in the post-monsoon months.

Metapenaeus dobsoni (Miers). This is one of the major species contributing to both the inshore fishery and the trawl fishery of the southwest coast of India extending to the Karwar coast. It is also common on the east coast, especially in Pulicat Lake and adjacent areas. It grows to a maximum length of 12 to 13 cm. The paddy field prawn fishery in the backwaters of Kerala is mostly dependant on the species; it breeds in the sea almost throughout the year and the postlarvae enter the backwaters, which serve as extensive nursery grounds, where it grows to about 6 to 7 cm. In the backwaters, estuaries and sea this species is caught throughout the year though the catch varies from month to month. In the monsoon period this species largely supports the fishery in the mud bank areas of the west coast.

Metapenaeus affinis (H. Milne Edwards). This is the most important commercial species of Metapenaeus, because of its occurrence along the entire west coast and the southern region of the east coast and because of its comparatively large size (maximum length 16 to 18 cm). Juveniles are caught in small numbers from backwaters, creeks and estuaries. The adult prawns are caught mainly during the post monsoon months, the peak season being October to December along the southwest coast. The immature prawns are fished almost throughout the year.

Metapenaeus monoceros (Fabricius). The maximum length is 17 to 19 cm. The contribution of this species to the fishery of each locality is comparatively small, but it is perhaps the only species of Metapenaeus occurring in the commercial fishery along the entire coast line of India. It also contributes to the estuaries and backwater fishery, where it attains a length of 10 to 11 cm. Breeding takes place in the offshore waters. As in M. affinis, the post-monsoon period is the best fishing season for this species. The immature prawns occur in varying quantities in all months of the year in the backwater and estuaries.

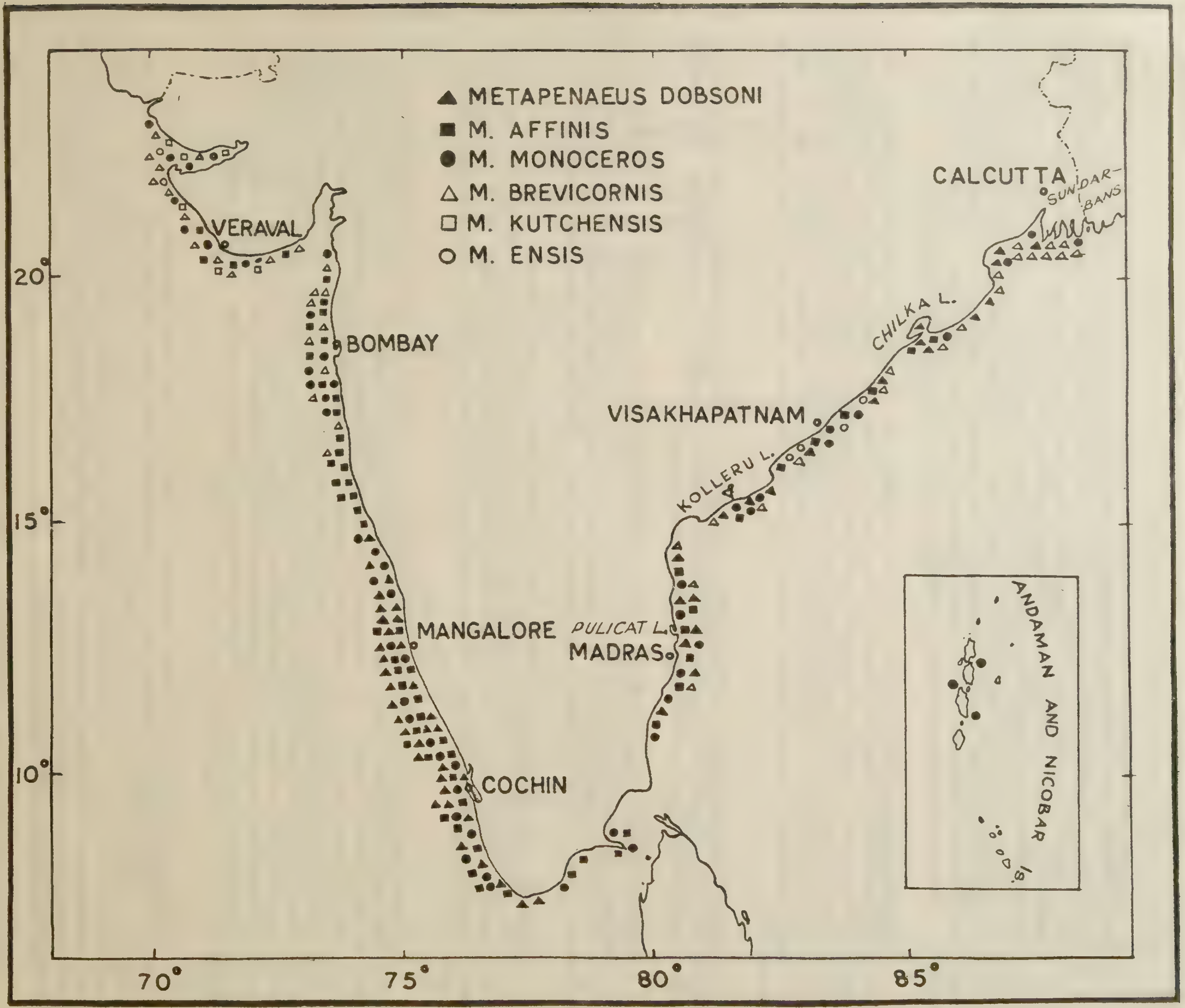
▲ METAPENAEUS DOBSONI
■ M. AFFINIS
● M. MONOCEROS
△ M. BREVICORNIS
□ M. KUTCHENSIS
○ M. ENSIS
CALCUTTA
SUNDAR-BANS
CHILKA L.
VISAKHAPATNAM
KOLLERU L.
PULICAT L.
MADRAS
VERAVAL
BOMBAY
MANGALORE
COCHIN
ANDAMAN AND NICOBAR Is.
20°
15°
10°
70°
75°
80°
85°

Fig. 2 Distribution of fishery for Metapenaeus spp.

Metapenaeus brevicornis (H. Milne Edwards). This is one of the commonest penaeid prawns of Bengal, inhabiting marine to almost freshwater zones throughout the year. It is common in the northern region of the west coast also, but does not occur in the southern region of either west or east coasts. The maximum length is about 13 cm. Spawning occurs in inshore waters. The larger individuals are taken from the inshore waters during the winter.

Metapenaeus kutchensis George *et al*. This prawn attains a maximum length of 14 to 15 cm and contributes a good percentage of the fishery in the Gulf of Kutch area.

Parapenaeopsis stylifera (H. Milne Edwards). Unlike other species this prawn is confined to the sea, and does not migrate to estuaries and backwaters. It is most common on the west coast, particularly in Bombay waters. Along the east coast, the species occurs in the southern region. It grows to about 14 cm and is caught throughout the year. It forms one of the main species in the inshore fishery.

Parapenaeopsis sculptilis (Heller). This species occurs in the marine fishery of the Hooghly (W. Bengal) in certain months, especially during winter, and in Bombay waters throughout the year, although it accounts for only about 4 percent of the catch in the latter area. It grows to a maximum length of about 15 cm, but the sizes obtained at Bombay are generally small. The larger specimens are generally caught in the inshore waters.

Parapenaeopsis hardwickii (Miers). This species, which grows to about 13 cm, is also present in Bombay waters, and is caught in small quantities along with other prawns.

Solenocera indica Nataraj. This is of commercial importance only in the inshore waters of Bombay, where it supplies about 10 percent of the catches. It grows to about 14 cm in length.

Trachypenaeus curvirostris (Stimpson). This is also caught in small numbers from Bombay waters. Small numbers of this species were also caught from further south during the exploratory and research cruises of R.V. VARUNA. The maximum length attained is about 10 to 12 cm.

3.2 Sergestids

Acetes indicus H. Milne Edwards. This is the largest among the commercially important sergestids and attains a maximum size of 3 to 4 cm. It occurs in vast shoals, either in midwater or near the surface, in the inshore waters near estuaries and backwaters. It makes a fairly large contribution to the fishery in the inshore waters of Bombay in certain months, and is also fished along the Bengal and Madras coasts.

Acetes erythraeus Nobili and *A. serrulatus* (Krøyer) are two other species of commercial importance, especially along the Madras and Malabar coasts. Besides providing an important fishery, shoals of these *Acetes* spp. form an important food for larger fishes.

3.3 Palaemonids

Most of the species inhabit fresh water but are capable of tolerating brackish water or even marine environments. The distribution of the fishery of important palaemonids of India is given in Fig.4.

Macrobrachium rosenbergii (de Man). This is the giant freshwater prawn, growing to a maximum length of 30 to 32 cm. It is common in most of the lakes and estuaries in India. Spawning takes place in the gradient zones of the estuaries. The young postlarvae ascend the rivers and the juveniles are caught mostly in the freshwater zones. The species contributes to a fairly large freezing industry in the Kerala backwaters,

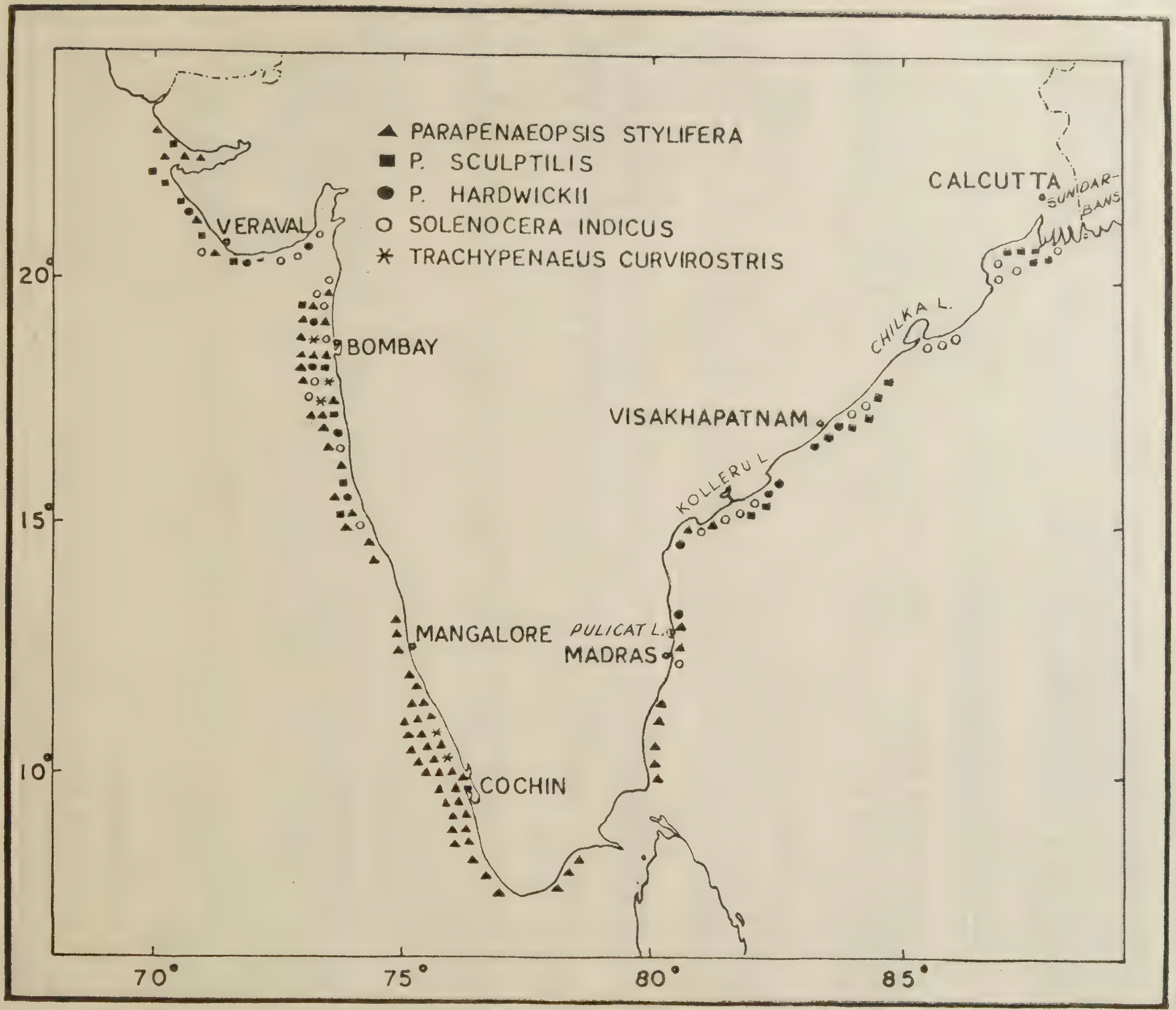
▲ PARAPENAEOPSIS STYLIFERA
■ P. SCULPTILIS
● P. HARDWICKII
○ SOLENOCERA INDICUS
✱ TRACHYPENAEUS CURVIROSTRIS
VERAVAL
BOMBAY
MANGALORE
COCHIN
PULICAT L.
MADRAS
KOLLERU L
VISAKHAPATNAM
CHILKA L.
CALCUTTA
SUNDAR-BANS
20°
15°
10°
70°
75°
80°
85°

Fig. 3 Distribution of fishery for *Parapenaeopsis*, *Solenocera* and *Trachypenaeus*.

during the monsoon and post-monsoon period. Along the east coast, the species is fished from December to July in the gradient zone, while the immature prawns are caught during other months from freshwater.

Macrobrachium malcolmsonii (H. Milne Edwards). This is a smaller species; females grow to 20 to 22 cm and males attain a considerably larger size. It is most common in the estuaries and lakes of Madras and Andhra and also in Chilka Lake. Habits are similar to those of the previous species. The limited fishery is during the monsoon months

Macrobrachium rude (Heller). Though caught in small numbers in most of the lakes and estuaries, this species is of commercial importance mostly in Bengal, Orissa and Andhra. The fishery season is from August to November. It attains a maximum length of about 12 to 13 cm, males being larger than females. In Bengal, the species occurs from August to October, in Chilka Lake it is fairly common from September to November. Young individuals are generally found during February and March.

Macrobrachium idae (Heller). This prawn attains a maximum length of 10 to 11 cm and is represented in the catches during September to December in the Kerala backwater areas and other regions.

Macrobrachium scabriculum (Heller), *M. mirabile* (Kemp) and *M. lamarrei* (H. Milne Edwards) are other species of this genus caught in small numbers in various estuaries and freshwater areas.

Palaemon styliferus H. Milne Edwards. This is one of the smaller palaemonids of commercial importance. It attains a maximum length of about 10 cm in both sexes and is very common in the Gangetic delta and also in Bombay waters, occurring in the tidal and gradient zones. Spawning occurs in the more saline areas and juveniles migrate to the estuary.

Palaemon tenuipes (Henderson). This species is fished along with the previous species in more or less the same areas. It grows to a maximum of 7 to 8 cm.

Leptocarpus fluminicola (Kemp). This is an endemic species inhabiting the brackishwater areas of the Gangetic delta. It grows to about 4 to 5 cm and is caught in very large numbers.

3.4 Hippolytids

Hippolysmata ensirostris Kemp. This is a small species (maximum length 8 to 9 cm) which is common in the Gangetic delta and the northern section of the west coast.

4 GENERAL REMARKS

In spite of the mechanization that has taken place in recent years, most of the prawn fishing in the sea is still conducted by the traditional methods, using indigenous gear and craft which vary from place to place. The most extensively used nets are boat seines and stake-nets, operated with the help of dugout canoes and carvel-built boats. However, the fishermen have realized the advantage of mechanization and shrimp trawling has come to stay. Quite a large number of boats, 7 to 11 m long, powered by 10 to 45 hp engines, are operating shrimp trawls, especially along the west coast. In the Bombay area, the indigenous craft have been fitted with in-board engines, and this has enabled the stake-net fishermen to transport their catches more quickly so that the prawns arrive at the landing and marketing centres in better condition than before and realize better returns. Mechanization has also enabled the fishermen to reach more distant and deeper areas than previously. In addition to the smaller vessels which go daily on fishing cruises, there are a few larger vessels, capable of staying out for longer periods, operating from Cochin.

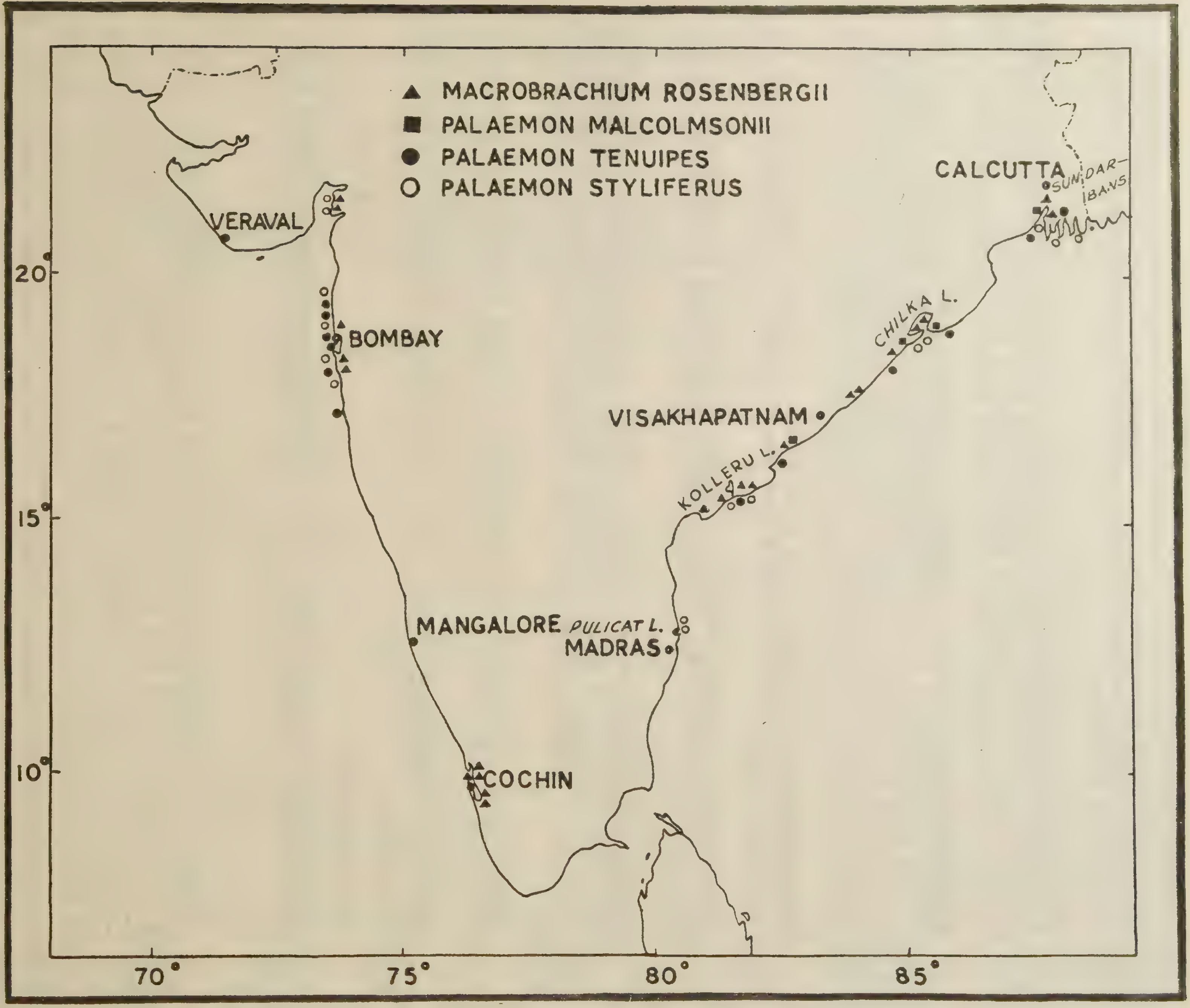
▲ MACROBRACHIUM ROSENBERGII
■ PALAEMON MALCOLMSONII
● PALAEMON TENUIPES
○ PALAEMON STYLIFERUS
CALCUTTA
SUNDARBANS
VERAVAL
BOMBAY
CHILKA L.
VISAKHAPATNAM
KOLLERU L.
MANGALORE
PULICAT L.
MADRAS
COCHIN
20°
15°
10°
70°
75°
80°
85°

Fig. 4 Distribution of fishery for palaemonids.

Most of the fishing is now carried out within the 20 fm (36 m) line. There appears to be scope for extending the fishing with advantage beyond this region. Preliminary exploratory fishing has shown the presence of a few species of deep water prawns, such as Aristaeus semidentatus, Penaeopsis rectacuta, Metapenaeopsis andamanensis, Heterocarpus woodmasoni, H. gibbosus, Parapandalus spinipes, and Plesionika martia, in depths between 100 and 200 fm (180 to 360 m) off the west coast. The potentialities of these from the commercial fisheries point of view remain to be studied.

At present the main fishing grounds are along the west coast. However, the existence of potential shrimp beds along the east coast, especially off large river mouths and brackish water lakes, cannot be ruled out. Exploratory work in this area remains to be carried out.

Another line of work which might help to augment the resources is by extension of prawn cultural practices in suitable areas. India has between 5,000 and 8,000 km^2 of estuarine and other brackish water areas, and at least a third of this could be converted with advantage for fish and prawn culture. Compatible fish and prawn species could be cultivated together.

Culture of the giant freshwater prawn Macrobrachium rosenbergii and its transplantation to suitable areas where it is not known to occur at present, could also be attempted.

A word may be said regarding the present trend in catches, and the fear that has been raised in some quarters as to whether any decline in prawn catches has resulted from the increased fishing activity in recent years. In any fishery, fluctuations in catches are bound to be encountered, even with the same level of catch effort. The variations in catches noticed in recent years are probably only natural fluctuations, as there is no evidence to indicate any definite decline due to over fishing. It is felt that there is still scope to increase the fishing effort to reach the optimum level of exploitation. Though precise data on the longevity of marine prawns are not available, those of tropical waters in general do not have a long life span. Most of the species live for between one and two years, within which time they grow and spawn. The fishery for each year-class must also be during this comparatively short period, as whatever is not caught will only perish. So long as sufficient brood stocks are left to ensure enough progeny for recruitment for the next season, there is no cause for fear of any over fishing. The situation is being carefully watched.

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COMMERCIAL PRAWNS OF WEST PAKISTAN

by

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Abstract

The paper is based on a study of the prawns collected from commercial catches along the West Pakistan coast. The twelve species represented belong to the three genera, Penaeus, Metapenaeus and Parapenaeopsis of the subfamily Penaeinae. Keys to the species are given, together with notes on important diagnostic features, size and colour. Juveniles showing interesting developmental stages of the thelycum and petasma are illustrated. Difficulties encountered in identifying several specimens belonging to the Penaeus indicus-orientalis complex are discussed. A brief survey of the prawn fisheries of Pakistan is included.

CREVETTES D'INTERET COMMERCIAL DU PAKISTAN OCCIDENTAL

Résumé

Le présent document se fonde sur une étude des crevettes prélevées dans des prises commerciales opérées dans les eaux côtières du Pakistan occidental. Les douze espèces représentées appartiennent aux trois genres Penaeus, Metapenaeus et Parapenaeopsis, de la sous-famille des Penaeinae. L'auteur décrit les caractéristiques de ces espèces et donne des indications sur d'importants facteurs d'identification, la dimension et la couleur. Des illustrations représentent des individus jeunes où l'on peut observer d'intéressants stades de développement du thelycum et du petasma. L'auteur expose les difficultés rencontrées dans la diagnose de plusieurs spécimens appartenant au complexe Penaeus indicus-orientalis. Le document contient également un bref exposé sur les pêcheries de crevettes du Pakistan.

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CAMARONES COMERCIAL DEL PAKISTAN OCCIDENTAL

Extracto

La monografía se basa en un estudio de los camarones recogidos en capturas comerciales efectuadas a lo largo de la costa del Pakistán Occidental. Las dos especies representadas pertenecen a los tres géneros Penaeus, Metapenaeus y Parapenaeopsis de la subfamilia Penaeinae. Se dan claves de las especies, junto con notas acerca de importantes características de diagnóstico, talla y color. Se ilustran formas juveniles que muestran interesantes fases de desarrollo del lycum y el petasma. Se discuten las dificultades encontradas al identificar varias especies pertenecientes al complejo Penaeus indicus-orientalis. Se incluye un breve estudio de las pesquerías de camarón de Pakistan.

1 INTRODUCTION

Pakistan has fairly large fisheries resources, and prawns occupy the most important position in the coastal fisheries. The present paper is based on the study of prawns collected from commercial catches of West Pakistan. Twelve species (not including the doubtful *Penaeus orientalis*), pertaining to the three genera *Penaeus*, *Metapenaeus* and *Parapenaeopsis* (subfamily Penaeinae) are represented. Species of *Penaeus* grow to a large size and make up the main bulk of landing. According to their size the prawns are locally named as 'jaira' (largest, reaching 8 in (203 mm) in length) 'kalri' and 'kiddi' (smallest, 3 to 4 in (76 to 102 mm) in length).

The following abbreviations are used: cl, carapace length, measured from the postorbital border to the posterior dorsal border; tl, total length, measured from tip of the rostrum to the apex of the telson. A schematic figure of the carapace (Fig. 1) is given to explain the various technical terms used in the paper.

2 SUBFAMILY PENAEINAE

Key to West Pakistan Genera of subfamily Penaeinae

(1) A pleurobranch present on last (eighth) thoracic somite; rostrum dentate on dorsal and ventral edges . . . . *Penaeus*

– No pleurobranch on last (eighth) thoracic somite; rostrum dentate on dorsal edge only . . . . (2)

(2) A pleurobranch on seventh thoracic somite; no longitudinal sutures on carapace; fifth pereiopod without exopod . *Metapenaeus*

– No pleurobranch on seventh thoracic somite; carapace with longitudinal sutures; exopods on all pereiopods . . . . *Parapenaeopsis*

2.1 Genus *Penaeus* Fabricius

Six species of *Penaeus* (and one doubtful species) are represented in the commercial catches. They are locally known as 'jaira'.

Key to West Pakistan species of genus *Penaeus*

(1) Adrostral grooves deep, extending almost to posterior margin of carapace; hepatic and gastro-frontal carinae well defined; thelycum in adult females pouch-like . . . . *P. japonicus* Bate

– Adrostral grooves not extending to posterior margin of carapace; hepatic carina present or absent, gastro-frontal carina absent . . . . (2)

(2) Adrostral grooves deep, extending at least as far as epigastric tooth; hepatic carina well defined . . . . (3)

– Adrostral grooves shallow, vanish at about level of epigastric tooth; hepatic carina absent . . . . (4)

(3) Fifth pereiopod with small but distinct exopod; hepatic carina inclined downwards in anterior half . . . . *P. semisulcatus* De Haan

– Fifth pereiopod without exopod; hepatic carina almost straight . . . . *P. monodon* Fabricius

(4) Maxillulary palp two-segmented . . . . (5)

– Maxillulary palp three-segmented . . . . (?) *P. orientalis* Kishinouye

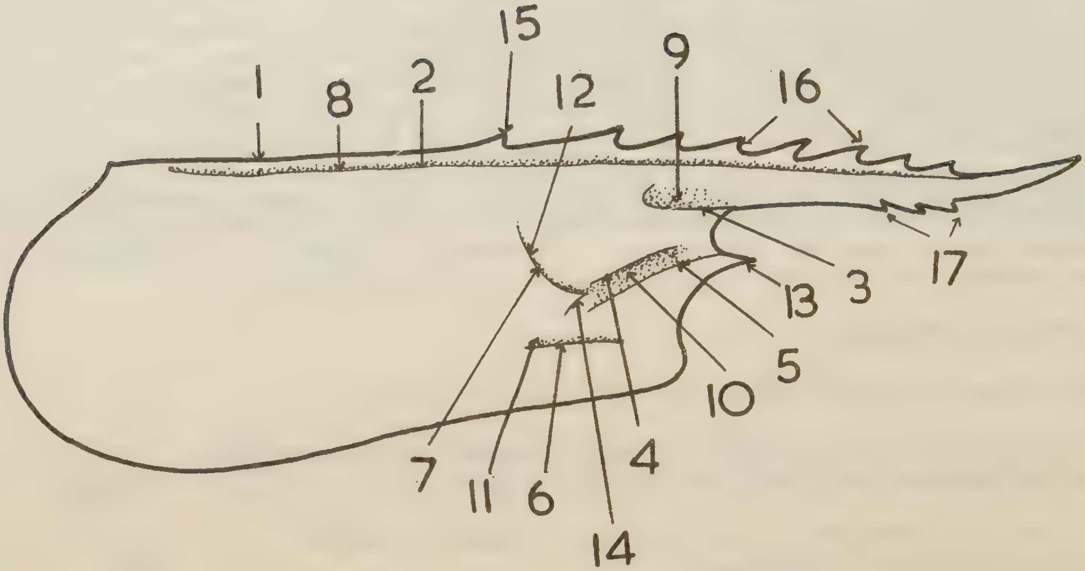

Fig. 1 Schematic figure of the carapace

Carinae: 1 post-rostral; 2 adrostral; 3 gastro-frontal; 4 gastro-orbital; 5 antennal; 6 hepatic; 7 cervical.

Grooves: 8 adrostral; 9 gastro-frontal; 10 gastro-orbital; 11 hepatic; 12 cervical.

Spines: 13 antennal; 14 hepatic.

Teeth: 15 epigastric; 16 upper-rostral; 17 lower rostral.

(5) Gastro-orbital carina occupying posterior 2/3 of distance
between hepatic spine and orbital angle . . . . *P. indicus*
H. Milne Edwards

- Gastro-orbital carina occupying middle 1/3 of distance
between hepatic spine and orbital angle . . . . (6)

(6) Dactylus of third maxilliped of adult male 1/2 length of
propodus; rostral crest high, triangular in profile; adrostral
carina not reaching as far as epigastric tooth . . . . *P. merguiensis*
De Man

- Dactylus of third maxilliped of adult male 1.5 to 2.7 times
length of propodus; rostrum convex in profile; adrostral
carina reaching just beyond epigastric tooth . . . . *P. penicillatus*
Alcock

2.1.1 *Penaeus japonicus* Bate Females rather rare, males extremely rare, in West Pakistan waters.

Diagnostic features

Carapace with 3 longitudinal grooves on dorsum, extending almost to posterior border; gastro-frontal groove broad and deep, posteriorly bifid; gastro-orbital groove also broad and deep; cervical groove narrow, reaching about mid-way to dorsum; hepatic groove narrow, curving downwards in its anterior half. Gastro-frontal, gastro-orbital, antennal, cervical and hepatic carinae well marked. Carapace armed with a large antennal and small but well defined hepatic spine. Gastro-frontal carina projects anteriorly as an acute process. Rostrum armed with 1+8-9/1 teeth (in the dorsal series, 1 denotes epigastric tooth). The carapace is illustrated in Fig. 2A. Abdomen with mid-dorsal carina extending from posterior half of 4th segment to posterior margin of last segment, ending in small sharp spine. Telson armed with 3 movable spines.

In males, petasma narrow and deeply channeled, with the disto-median lobes (dm) recurved to form a sort of hood (Fig. 2B).

Thelycum pouch-like in adult females (Fig. 2C) but of different form in young females. Specimen of cl 11.5 mm (Fig. 2D) has U-shaped plate between 5th pair of pereiopods, produced into anterior lobe (l) on each side; triangular plate between 4th pair of pereiopods has sharp spine at apex and 2 small projections on posterior border. In specimens of cl 21 mm, lobes between fifth pereiopods become more pronounced and anterior border of median part of U-shaped plate grows forwards as far as median spine of last thoracic sternite; triangular plate becomes concave shield with setose lateral margins. Specimen of cl 24 mm shows pouch-like form developing. Characteristic form of adult thelycum assumed by specimens of cl about 31 mm (Tirmizi, 1958). In large specimens, anterior border of ventral wall of thelycum grows forward and conceals dorsal walls (Fig. 2C).

Fresh specimens of *P. japonicus* exhibit 2 colour patterns: (i) body pale pink with bright orange and black stripes on abdomen, carapace with black markings, distal part of uropods and telson also black; (ii) body either pale pink or blue with black stripes; antennae, pereiopods and pleopods yellow; distal half of exopod of each uropod bright yellow, with distal border blue, fringed with carmine setae; telson has yellow and blue bands.

Local name: Tiger prawns

Maximum size: tl 216 mm (female)

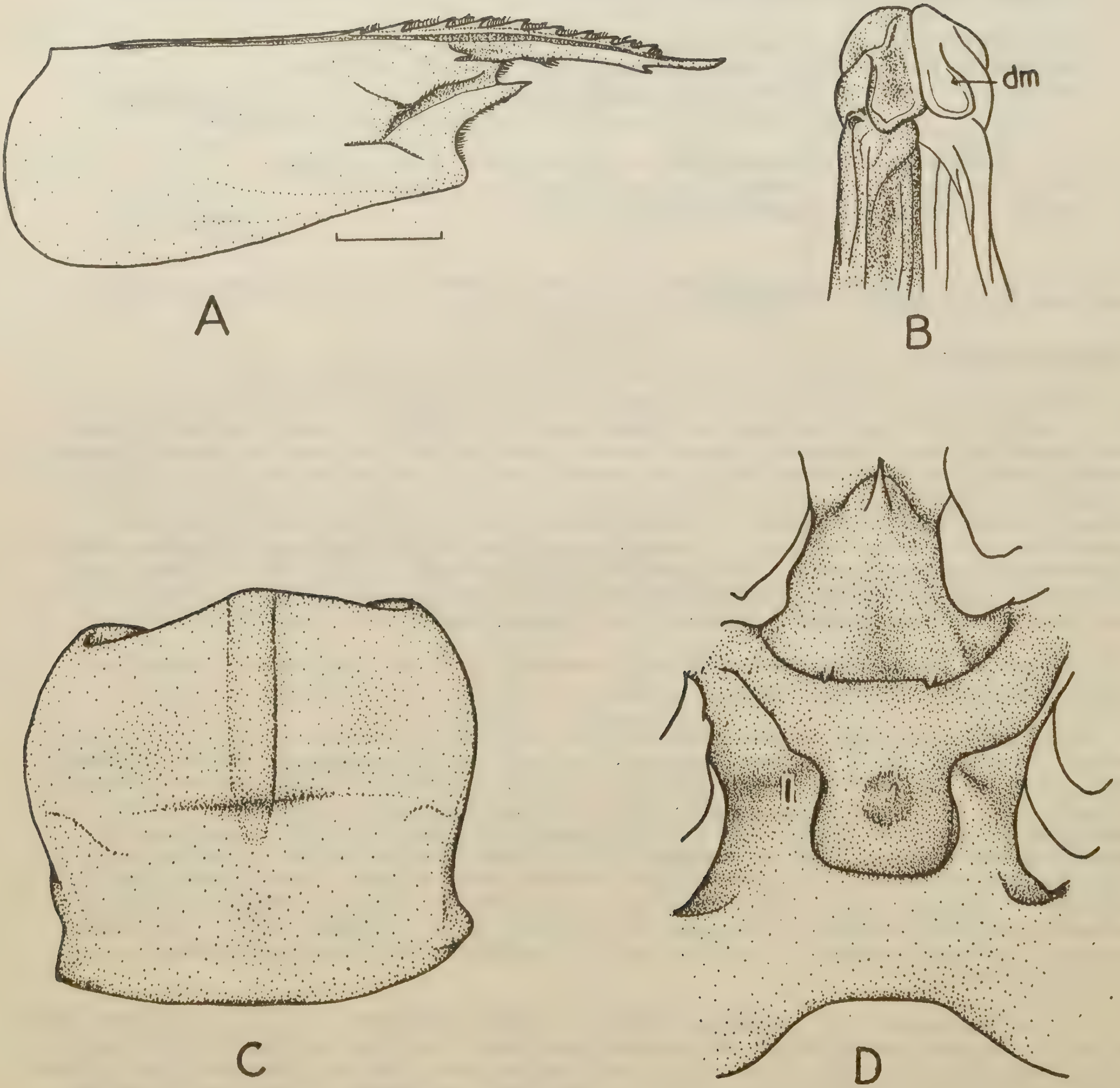

Fig. 2 Penaeus japonicus Bate
A carapace in lateral view (scale = 10 mm);
B distal part of petasma in ventral view, from specimen of cl 37 mm (dm = distomedian lobe);
C thelycum of adult female of cl 31 mm;
D early stage in formation of thelycum (l = lobe-like projection).

2.1.2 *Penaeus semisulcatus* De Haan This species is fairly well represented in West Pakistan.

Diagnostic features

Post-rostral carina sulcate, reaching almost to posterior margin of carapace; adrostral grooves extending just beyond epigastric tooth; gastro-frontal and gastro-orbital grooves shallow; hepatic and cervical grooves narrow; hepatic groove inclined downwards in its anterior half. Orbito-antennal, antennal, cervical and hepatic carinae well defined; gastro-frontal absent; antennal and hepatic spines about equally developed. Rostrum with 1+6-7/2-3 teeth. Abdomen with mid-dorsal carina extending from posterior half of 4th segment to posterior margin of last, ends in a small, sharp spine. Telson unarmed. Small exopod on 5th pereiopod (absent in *P. monodon*).

Petasma resembles that of *P. japonicus* except that it is rather open and disto-median lobes are small.

Thelycum consists of 2 lateral plates (occupying space between 5th pereiopods) and median anterior plate. Raised median margins of lateral plates approximate in mid-line. Median plate has median longitudinal ridge on posterior half. Anterior margin of plate somewhat arc-shaped.

Freshly preserved specimens have cream coloured body and legs with steel grey stripes, rami of pleopods grey with carmine setae, distal half of pleopods grey, fringed with carmine setae.

Maximum size: tl 230 mm (impregnated female).

2.1.3. *Penaeus monodon* Fabricius This species is rather rare.

Diagnostic features

P. monodon is closely related to *P. semisulcatus* but attains a much greater size.

Post-rostral carina with shallow groove; adrostral grooves vanishing before epigastric tooth; gastro-orbital carina small, occupying posterior 1/3 of distance between hepatic spine and orbital angle; hepatic carina almost straight. 5th pereiopod without exopod. Rostrum with 1+7/3 teeth. Disto-median processes of petasma small, lobe-like and sub-apical.

Maximum size: tl 330 mm (female).

2.1.4 (?) *Penaeus orientalis* Kishinouye Not very common.

Remarks

P. orientalis is so far known from Northern China, Japan, Korea and Hong Kong (Cheung, 1960). In the present collection there are several specimens, belonging to both sexes, which show all the characters of *P. orientalis*, including the form of the thelycum (Fig. 3B) and the appendix masculina. They also have the maxillulary palp 3-segmented, a character which separates *P. orientalis* from the closely related *P. indicus*. According to Kubo (1949:302) the 3rd pereiopods extend "... as far as antennal scale". In my specimens the 3rd pereiopods reach to or beyond the tip of the scale, except in one specimen, a female of cl 14.5 mm, in which they are short and extend to about 2/3 of the length of the scale. The anterior part of the carapace of a male is illustrated in Fig. 3A.

Largest specimen measures 155 mm (tl)

Apart from these there are several problematical specimens of up to 177 mm (tl) in which the maxillulary palp of 1 side is 2-segmented and that of the other 3-segmented (Fig. 3C). The thelycum and appendix masculina of these specimens resemble those of *P. indicus*.

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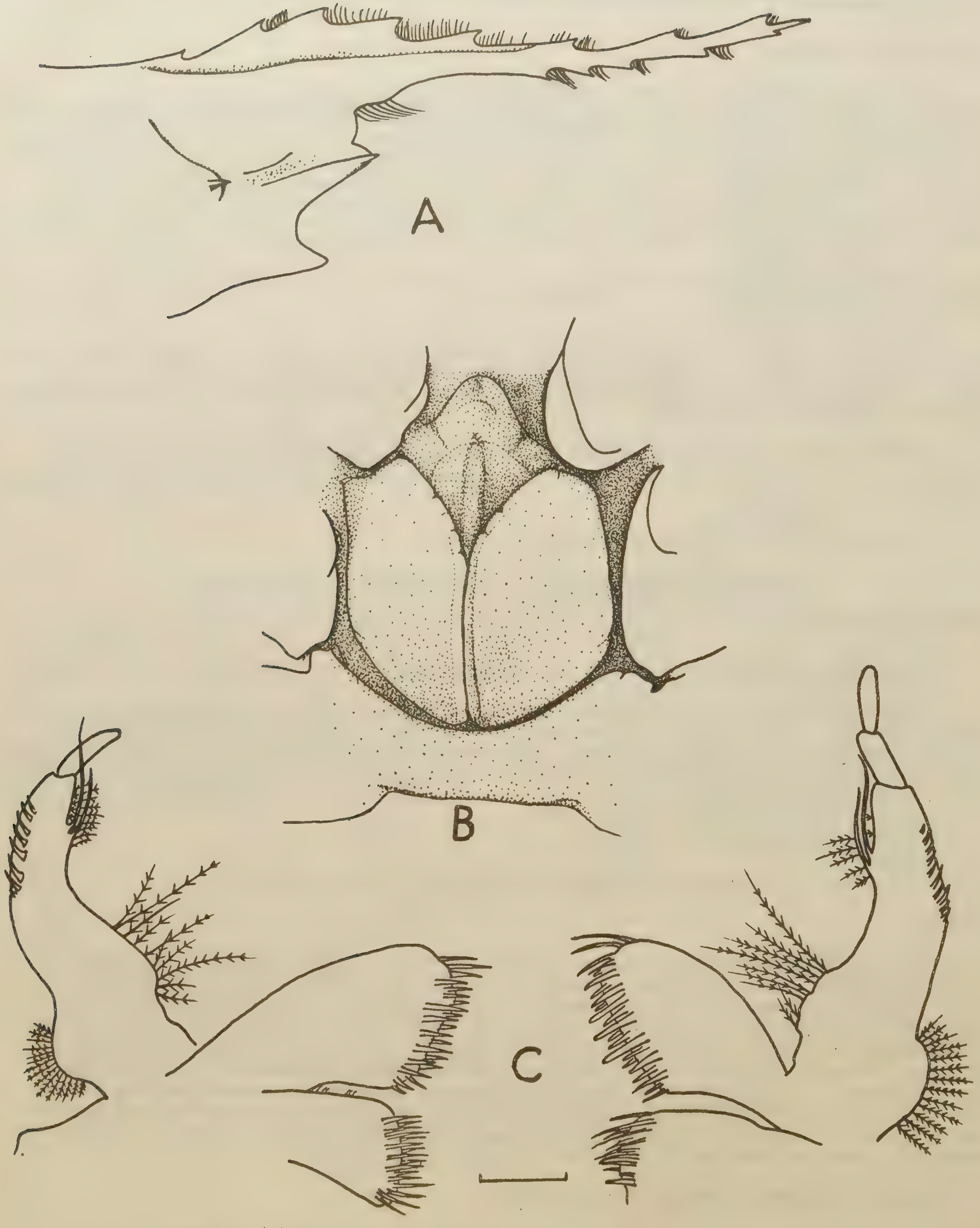

Fig. 3 (?) *Penaeus orientalis* Kishinouye
A anterior carapace, lateral (scale = 5 mm);
B thelycum (scale = 1 mm);
C right and left maxillules of a specimen showing
variation in the segmentation of the palps (scale = 1 mm).

2.1.5 Penaeus indicus H. Milne Edwards This species is also rare.

Diagnostic features

Post-rostral carina not grooved (marked with a few pits); adrostral grooves reach just below epigastric tooth; gastro-frontal groove shallow; gastro-orbital broad and rather deep, cervical narrow; hepatic groove absent; adrostral, gastro-orbital, antennal and cervical carinae well marked, gastro-orbital occupying about posterior 2/3 of the distance between hepatic spine and orbital angle. Rostral crest high; rostrum armed with 1+6-8/4-5 teeth. Mid-dorsal carina of abdomen resembles that of previous species; telson unarmed. In adult males the dactylus of 3rd maxilliped is as long as the propodus.

Petasma not deeply channeled; disto-median lobes small, slightly recurved, extending beyond lateral lobes.

Thelycum consists of 2 lateral plates which form an almost circular seminal receptacle; only small anterior portion of median plate visible.

The body is cream coloured, speckled with grey.

Maximum size: tl 193 mm (female).

2.1.6 Penaeus merguiensis De Man This species outnumbers all the others in catches in the coastal waters of West Pakistan.

Diagnostic features

There is a fairly close resemblance to P. indicus.

Rostral crest high and triangular, rostrum armed with 1+6-7/3-5 teeth. Adrostral carina does not reach as far as epigastric tooth, gastro-orbital carina occupies middle 1/3 of the distance between hepatic spine and gastro-orbital angle. Dactylus of 3rd maxilliped 0.5 to 0.6 times length of propodus in adults.

Disto-median lobes of petasma acute and extend beyond apex; the seminal receptacle oval in outline.

Maximum size: tl 240 mm (female).

2.1.7 Penaeus penicillatus Alcock This species is also very common in the commercial catches.

Diagnostic features

P. penicillatus can be differentiated from the previous species by the following points.

Rostral crest convex, rostrum armed with 1+5-7/3-5 teeth; adrostral carina extends just beyond epigastric tooth, dactylus of 3rd maxilliped 1.5 to 2.7 times the length of propodus in adult specimens. Distomedian lobes of petasma small rounded and do not extend beyond apex of lateral lobes. Outline of seminal receptacle almost circular.

Maximum size: tl 210 mm (female).

2.2 Genus Metapenaeus Wood-Mason

This genus is represented by 4 species. All are fairly large, and all except M. monoceros are abundant in the catches.

Key to West Pakistan species of genus *Metapenaeus*

(1) Distomedian projections of petasma style-like; thelycum with or without C-shaped lateral plates . . . . (2)

- Distomedian projections of petasma not style-like; thelycum with C-shaped lateral plates . . . . (3)

(2) Distomedian styles of petasma straight, stiff and ventrally serrated; lateral plates of thelycum triangular, median plate an inverted T . . . . *M. stebbingi* Nobili

- Distomedian styles of petasma dorsally curved, rather flexible, ventral margin not serrated; lateral plates of thelycum C-shaped, anterior part of median plate sub-quadrangular . . . *M. brevicornis* (H. Milne Edwards)

(3) Distomedian projections of petasma, thick and convoluted; lateral plates of thelycum C-shaped with raised lateral margins, median plate narrow, tongue-like and with a deep groove . . . *M. monoceros* (Fabricius)

- Distomedian projections of petasma almost crescent shaped; lateral plates of thelycum C-shaped but small and rounded apically, median plate inverted Y-shaped, with shallow groove . *M. affinis* (H. Milne Edwards)

2.2.1 *Metapenaeus stebbingi* Nobili This species was first recorded from West Pakistan in 1962 (Tirmizi, 1962). It seems to be fairly well represented in the local catches.

Diagnostic features

Gastro-orbital carina oblique, ridge-like; antennal and cervical carinae present; gastro-orbital groove gradually widening anteriorly; cervical groove well defined both above and below hepatic spine; post-rostral carina not traceable on posterior half of carapace; rostrum armed with 1+8-9 teeth (Fig. 4). Abdomen with mid-dorsal carina extending from posterior half of 4th abdominal somite to posterior margin of 6th, ends in sharp spine; telson armed with row of spinules on each lateral border.

Each petasmal half with dorso-median style, armed ventrally, and 3 laterally directed projections.

Thelycum consists of median plate resembling inverted T, situated on last sternite (between 5th pereiopods); triangular plate on either side with apex directed posteriorly and fitting closely to hollows of T-shaped median plate.

The body is pale, speckled with grey and rust. Outer half of the exopod and distal half of the endopod of uropod are rust coloured.

Maximum size: tl 120 mm. The smallest specimen recorded by the author is only 25 mm (tl).

2.2.2 *Metapenaeus brevicornis* (H. Milne Edwards)

Diagnostic features

Gastro-frontal antennal and gastro-orbital carinae all faint; cervical groove well defined both above and below hepatic spine; post-rostral carina extending almost to posterior margin of carapace; rostral crest high and triangular, rostrum armed with 1+4-5 teeth, distal half or less edentate; rostrum either extending as far as distal margin of last segment of antennular peduncle, or may be short, not reaching beyond

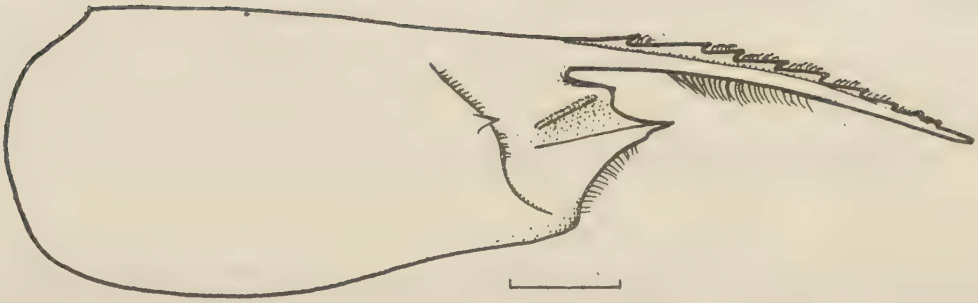

Fig. 4 Metapenaeus stebbingi Nobili, carapace in lateral view. (scale = 5 mm).

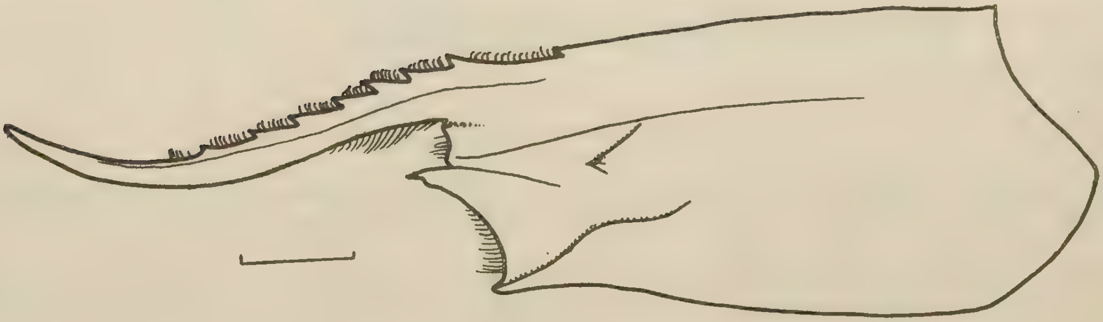

Fig. 6 Parapenaeopsis stylifera (H. Milne Edwards), carapace in lateral view. (Scale = 5 mm)

penultimate segment. Abdomen with mid-dorsal carina on middle of 3rd segment and continuous from posterior part of the 4th segment to posterior margin of last; ends bluntly or in acute process. Telson armed with 3 to 4 pairs of spines.

Petasma with dorsally curved disto-median styles, which are not serrated, spout-like projections directed antero-laterally.

Thelycum with median and 2 lateral plates; median plate broad, sub-quadrangular, lateral plates C-shaped.

2.2.3 Metapenaeus monoceros (Fabricius)

Diagnostic features

Carapace very similar to that of M. brevicornis; rostrum long extending as far as distal margin of last segment of antennular peduncle, armed with 1+8-9 teeth; rostral teeth extending almost to tip; lateral margin of telson armed with rows of microscopic spines.

Petasma with thick, convoluted disto-lateral processes.

Thelycum with median plate narrow, tongue-like and ventrally grooved; lateral plates C-shaped, lateral margin of each plate raised giving cup-like appearance to seminal receptacle.

Maximum size: tl 190 mm.

2.2.4 Metapenaeus affinis (H. Milne Edwards)

Diagnostic features

Differs from the previous species in the following:

Rostrum long extending beyond antennular peduncle, armed with 1+7-10 teeth; distal 1/3 unarmed. 3rd abdominal somite without mid-dorsal carina.

Petasma with crescent-shaped disto-lateral projections. Petasma of young males, showing early development stages, are illustrated in Fig. 5.

Median plate of thelycum broader and resembling an inverted Y; lateral plates small, C-shaped.

Maximum size: tl 186 mm.

2.3 Genus Parapenaeopsis Alcock

Only 2 species of this genus are netted along the West Pakistan coast. They can be separated by the following key:

Key to West Pakistan species of genus Parapenaeopsis

(1) Rostrum extending beyond antennular peduncle, distal 1/2 styliform and edentate, strongly upcurved; outer antennular flagellum as long as carapace; petasma with slender, tube-like projections directed antero-laterally; thelycum without median tuft of setae; telson armed . . . . P. stylifera (H. Milne Edwards)

- Rostrum not extending beyond antennular peduncle, distal 1/4 styliform and edentate, slightly upcurved; outer antennular flagellum about 1/2 the length of carapace; petasma with short wing-like processes directed antero-laterally; thelycum with median tuft of setae; telson unarmed . . . . P. sculptilis (Heller)

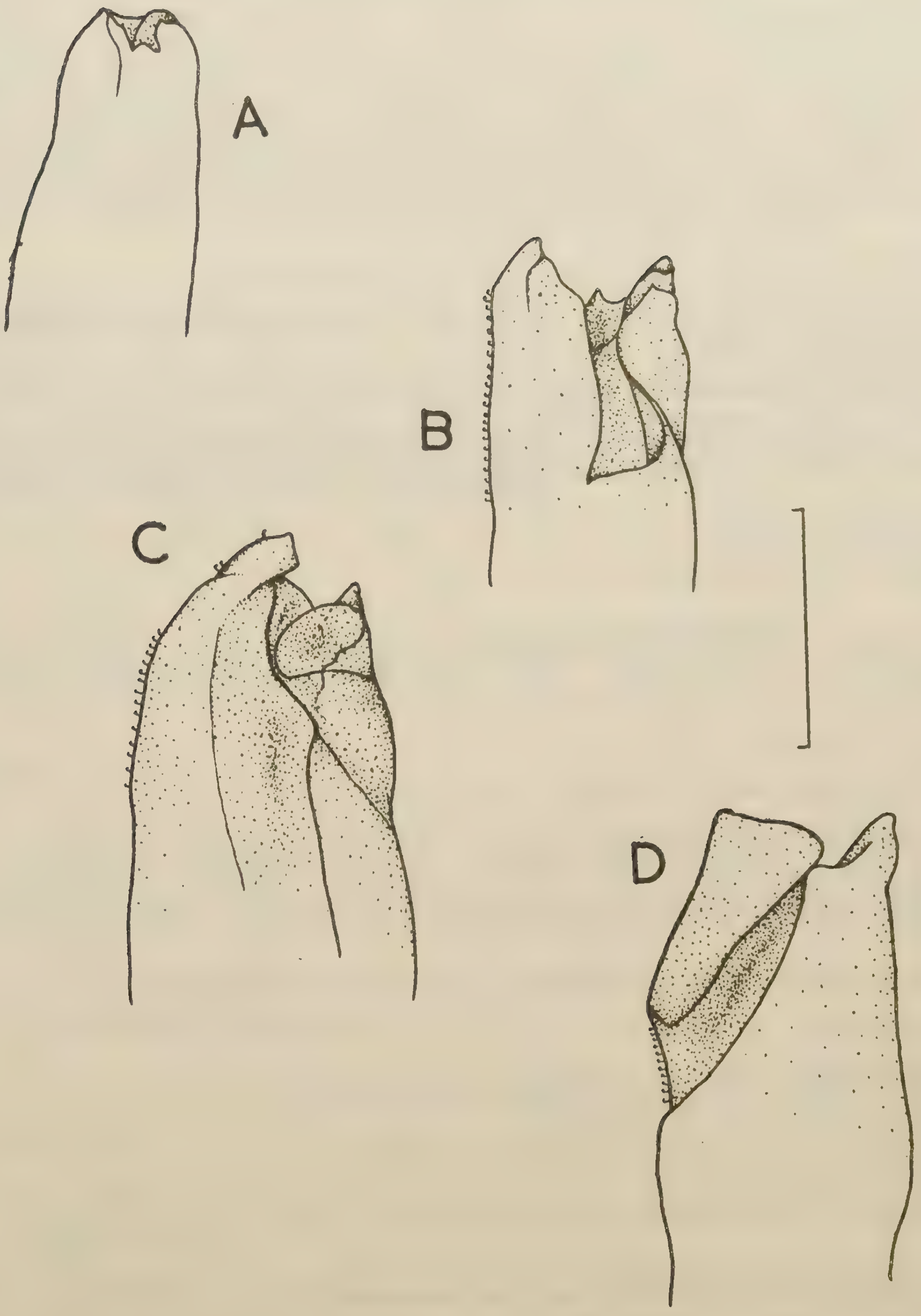

Fig. 5 *Metapenaeus affinis* (H. Milne Edwards), developmental stages of the petasma (distal, left half). cl of specimens: A, 13 mm; B, 16 mm; C, 18 mm; D, 20 mm. (Scale = 0.5 mm)

2.3.1 Parapenaeopsis stylifera (H. Milne Edwards) This species is very common in the creeks and is an important economic species.

Diagnostic features

Post-rostral carina extending almost to posterior border of the carapace, adrostral not reaching as far as epigastric tooth, gastro-frontal hardly marked, antennal carina well developed; longitudinal suture on anterior half of the carapace; antennal and hepatic spines present; rostrum long, styliform, extending far beyond antennular peduncle, armed with 1+4-7 teeth, edentate in its distal half, which is upcurved (Fig. 6). Abdomen with mid-dorsal carina on somites 4 to 6; telson armed with 4 pairs of spines.

Petasma with long, tube-like disto-median projections.

Thelycum with broad anterior plate, and posterior plate which is deeply notched on middle of anterior half.

Body light pink speckled with grey spots; tips of uropods dark. The species usually has a good taste. Along with 'normal' specimens are also found some which show no morphological differences but each abdominal segment has a conspicuous white band. These specimens have a bad taste and spoil the quality of the others.

Local name: Kiddi.

Maximum size: 120 mm (tl).

2.3.2 Parapenaeopsis sculptilis (Heller) . Though represented in the commercial catches, the meat is not relished and specimens of this species are generally removed.

Diagnostic features

P. sculptilis can be separated from P. stylifera by the following:

Rostrum shorter, extending at most to just beyond antennular peduncle. Mid-dorsal carina on posterior 3/4 of each of first 3 abdominal segments. Petasma with wing-like disto-median projections and spout-like lateral projections. Thelycum with median tuft of setae on posterior plate, posterior plate not notched.

General surface of body pale pink, with broad black stripes.

Maximum size: tl 170 mm.

3 A BRIEF SURVEY OF PRAWN FISHERIES IN WEST PAKISTAN

The fisheries resources of Pakistan are fairly large but, unfortunately, the extent of these resources has not yet been assessed.

The coast of West Pakistan may be divided into two distinct regions.

(a) Karachi and Sind coast: Extends from Karachi in a southeasterly direction. It is characterized by a net-work of creeks ending in Sir Creek which forms a boundary between Pakistan and India. The coast is about 200 mi (320 km) long. It is shallow and very gradually slopes outwards. The 100 fm (180 m) line is about 60 mi (about 100 km) from the coast, except at the mouth of the River Indus, where the sea becomes abruptly deep. Very few trees are present on the coast except the mangroves which thrive very well. There are a few villages and temporary habitations spring up during the fishing season, and they move according to the catch.

(b) Mekran coast: Extends from Hub River to Gwatar Bay. It is about 350 mi (570 km) long and rather steep; the 100 fm line is 25 to 30 mi (40 to 50 km) off the coast. The entire coast is dry and barren and is formed of successive depressions and folds, chains of low and steep hills of soft stone run more or less parallel to the coast-line, which is intersected by bays and small sandy plains. The coast is dotted with about 21 fishing settlements of both temporary and permanent nature.

The shrimp season in West Pakistan commences in October and continues till the end of April. The best period, however, is from November to the middle of March. It is during this period that the shrimps and prawns of best commercial value are available. Small prawns locally known as 'bonkey' are available in July and August.

The fishing fleet of West Pakistan consists of about 5,500 boats, including trawlers, launches, sailing boats and a few row boats. Average yearly catch on the Sind and Mekran coast is about 8,000 tons. Local consumption is very little and the prawns are exported to several countries. Frozen prawns are much in demand, and the main bulk goes to U.S.A. Dried and canned prawns are also exported.

West Pakistan, at present, has about 21 fish processing plants, but due to insufficient landing all the plants are not in operation. It is estimated that the maximum utilization is only 30 percent of the capacity.

The reason for this dearth in catches is probably due to inadequate knowledge about the prawns. The local fishermen are unaware of the breeding grounds and know very little about the migration of these shrimps.

Since prawns and shrimps play an important role in the economy of our country it is necessary to gain further knowledge about them. While measures are being taken to introduce modern methods for fishing, equal importance should be given to the preservation of stocks.

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THE VENEZUELAN SHRIMP INDUSTRY

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Abstract

Shrimps support the most important fishery in Venezuela. The major fishery is located in the western region near the Lake of Maracaibo and the Gulf of Venezuela, and 98 percent of the national production comes from this area. In 1966, a drastic drop in production was responsible for the closure of many processing plants. Proposed restrictions around the mouth of the lake have caused concern because of their possible effect on shrimp movement. Fishing effort has increased so rapidly that many scientists are wondering to what extent this increase can continue. Primarily because of these problems, the government and industry have united to encourage investigations into the biology of the stocks that support the fishery. The Instituto Venezolano de Investigaciones Científicas has been carrying out such investigations since 1963 and it is hoped that the proposed expansion of this work will supply the answer to many of the questions being raised today. Information so far obtained reveals that five out of the nine species of shrimp found in the area are present in commercial quantities, the three most important being Penaeus schmitti, P. aztecus and P. duorarum. Their distribution and relative importance are discussed.

E/41

LES PECHERIES VENEZUELIENNES DE CREVETTES

Résumé

La plus importante des pêches vénézuéliennes repose sur les crevettes. La principale pêcherie se trouve dans l'ouest, où la zone du lac de Maracaibo et du golfe de Venezuela fournit 98 pour 100 de la production nationale. L'industrie se heurte à de nombreuses difficultés, et en 1966 une forte baisse de la production a entraîné la fermeture de nombreuses usines de transformation. Un projet de construction d'ouvrages au débouché du lac a suscité des craintes, étant donné les répercussions possibles sur les déplacements des crevettes. L'effort de pêche s'est accru si rapidement que beaucoup d'hommes de science se demandent si la progression pourra se poursuivre longtemps. C'est en grande partie à cause de ces problèmes que les pouvoirs publics et l'industrie ont uni leurs efforts pour encourager l'étude de la biologie des stocks alimentant la pêcherie. L'Instituto Venezolano de Investigaciones Científicas s'acquitte de cette tâche depuis 1963, et l'on espère que l'expansion envisagée de ses travaux fournira la réponse à maintes questions qui se posent aujourd'hui. D'après les renseignements obtenus jusqu'ici sur les 9 espèces de crevettes de la zone de pêche, 5 sont suffisamment nombreuses pour présenter un intérêt commercial, les trois plus importantes étant *P. schmitti*, *P. azteous* et *P. duorarum*. La communication examine leur répartition et leur importance relative.

LA PESQUERIA DE CAMARONES DE VENEZUELA

Extracto

La pesquería más importante de Venezuela es la de los camarones, hallándose situada en la región occidental cerca del lago del Golfo de Maracaibo; el 98% de la producción nacional procede de esta zona. La industria tiene muchos problemas y en 1966 una grave baja de la producción dio lugar a que se cerraran muchos establecimientos de elaboración. Las restricciones propuestas alrededor de la salida del lago han causado preocupación por sus posibles consecuencias sobre el movimiento de los camarones. El esfuerzo de pesca ha aumentado con tanta rapidez que muchos especialistas se preguntan hasta cuándo podrá continuar este incremento. Debido principalmente a estos problemas, el gobierno y la industria han decidido estimular conjuntamente las investigaciones sobre la biología de las poblaciones y la pesquería. El Instituto Venezolano de Investigaciones Científicas viene realizando tales investigaciones desde 1963 y se espera que la propuesta expansión de esta labor proporcionará la respuesta a muchas de las cuestiones que se plantean hoy. La información obtenida hasta ahora revela que cinco de las nueve especies de camarones presentes en la zona existen en cantidades comerciales, siendo los tres más importantes *P. schmitti*, *P. aztecus* y *P. duorarum*. Se examina su distribución así como su importancia relativa.

1 INTRODUCTION

Shrimp support the most valuable fishery in Venezuela. In 1965, a total national production of more than 7 million kg was reported (M.A.C., 1965). This represents a value of approximately $ 2.6 million to the fishermen and, because of its importance as an export commodity, its value to the economy of the country is substantially greater. More than 13 million lb (6 million kg) of frozen (heads-off) product were marketed outside the country in 1965. After only a very few years, this industry has developed into one of considerable importance. Such importance is reflected in the fact that a rather abrupt drop in production last year drew considerable international, as well as national attention.

The important coastal fisheries of the country are located at the extremes of its 2,800 km coastline. It is here that the continental shelf is widest, and it is here that one finds the great estuarine systems of Lake Maracaibo and the Orinoco River Delta. The famous sardine fishery is located in the east and the young but rapidly growing shrimp industry is in the west.

Western Venezuela (Gulf of Venezuela, Lake Maracaibo) accounts for approximately 98 percent of the national production of shrimp. Small local seasonal fisheries exist in the Unare and Piritu lagoons in the east, and renewed effort is now underway to exploit the potentially rich waters off the Orinoco River Delta, but production from these areas is small. This report will concentrate on the western shrimp fishery because of its relative importance and because much more information is currently available on it.

2 FISHING EFFORT

Great contrast exists in shrimp fishing techniques, from the very primitive to the highly mechanized. Trawling is prohibited by law in areas where most of the inshore shrimp (camarones) are found. Instead, several types of beach nets are used: 'atarraya' (a small cast net), 'copita' (a small beach seine used by two men), and 'mandinga' (a large beach seine, 100 m or more in length, fished by five or six men). The mandinga is most used. Small dugout boats (chalana), frequently powered by 40 hp outboard motors, are used to transport men and gear to areas of Lake Maracaibo where shrimp are found, and to return the catch to traditionally designated landing areas. There are approximately 5,000 men fishing the Lake and 3,000 of these use mandinga to fish shrimp. The limitations of this gear prevent fishing in waters of depths of more than a few meters.

Offshore shrimp (langostino)[1] populations are fished by trawlers of two types. Stern trawlers of Italian design arrived in the Gulf of Venezuela in 1954 and fished from Puerto Cabello. They came initially for fish, but, as the fleet grew in size and fishing effort increased, the extensive shrimp resources of the area were discovered and utilized. The second type, Gulf of Mexico double-rigged trawlers, arrived from Central American ports about 1957, and fishing for shrimp began in earnest. The Venezuelan shrimp export market began in 1958 and, as a result, an important fishing industry has developed over a short period of time. Today 48 trawlers are based on Punto Fijo, on the western coast of the Paraguana Peninsula, the majority of these are of the Italian type, up to 85 ft (26 m) in length. There are 14 rather smaller Gulf of Mexico type boats based on Maracaibo. New boats are on order and it is anticipated that the trawler fleet may double in size in the next few years. Two Gulf of Mexico type trawlers, based at the new fishing port of Guiria, have recently begun fishing in the Gulf of Paria (in Eastern Venezuela) on an exploratory basis. Trinidad based boats have in the past fished off the Orinoco Delta, but with reportedly limited success.

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[1] In Venezuela, this term is used for the larger Penaeidae; in Chile, it is used for Galatheidae (Ed.)

3 PRODUCTION

The Venezuelan Ministry of Agriculture (Ministerio de Agricultura y Cría) has for several years maintained local fishery offices (inspectorías) in strategic landing areas for the purpose of administering the fisheries of the country. Records are kept of production, but some of the data are of questionable accuracy due to the complexity of the fishery and to the manner in which they are collected. Procedures are being refined and more accurate data should be available in the future.

Several important facts, however, can be extracted from present information. Shrimp is by far the most important Venezuelan fishery (Table I). Though annual sardine production (43 million kg in 1965) greatly surpasses shrimp production (7.4 million kg) by weight, its value to the fisherman (3 million Bs) is less than one-fifth that of shrimp (14 million Bs). The snapper (pargo) fishery ranks second in value but produces only half the revenue of shrimp. Of the 7.4 million kg of shrimp produced in 1965, 7.1 million kg (or 96 percent) were taken from western Venezuela (approximately two-thirds of this from the Gulf of Venezuela and one-third from Lake Maracaibo).

TABLE I

The major Venezuelan fisheries in order of their production and value, and the species contributing to these fisheries (Source: Ministerio de Agricultura y Cría, 1965)

NATIONAL FISHERY PRODUCTION, 1965					
Rank	Species	Production (kg) (1,000 kg)	Rank	Species	Value (Bs) (1,000 Bs)
1	Sardine	43,740	1	Shrimp	14,265
2	Shrimp	7,473	2	Snapper	6,005
3	Croaker	5,847	3	Mackerel	5,252
4	Manamana	4,516	4	Croaker	5,030
5	Aroa	3,955	5	Tuna	3,710
6	Mackerel	3,392	6	Sardine	3,047
7	Snapper	2,828	7	Grouper	2,911
8	Grunt	2,826	8	Jack	1,765

Sardine (Sardina) - Clupanodon sp., Harengula sp., Sardinella sp.
Shrimp (Camarón, Langostino) - Penaeus schmitti, P. duorarum, P. azteous and P. brasilensis, Xiphopenaeus kroyeri
Croaker (Curbina) - Cynoscion sp.
Snapper (Pargo) - Lutjanus analis, L. aya, L. griseus

Mackerel (Cariet) - Scomberomorus maculatus
Manamana - Suprasinelepichthys laticeps
Arca (Pepitona) - Arca sp.
Tuna (Atún) - Caranx crysos, Thunnus albacares, T. thynnus, T. obesus
Grouper (Mero) - Epinephelus striatus
Jack (Jurel, Jurelete) - Caranx sp.

4 REGULATIONS

Both governmental and self-imposed regulations are in effect on the shrimp fisheries. Each year both trawler skippers and small boat owners are required by the Venezuelan government to obtain new licenses to fish. Licenses can be revoked for failure to abide by certain established rules on the type of gear used, on the size of netting, on prohibited areas, and also for failure to submit records of catch.

Probably the most controversial of these rules prohibits fishing by trawlers south of an imaginary line running from the mouth of the Paijana river (on the southwestern shore of the Gulf) to Punto Adaro (on the Paraguana Peninsula). The rule also prohibits trawler fishing within eight miles of the shoreline north of this line. This theoretically eliminates Lake Maracaibo and a considerable area of the Gulf from trawler fishing. In practice, the government finds the rule impossible to enforce, and it is not greatly interested in its enforcement. The rule resulted from the bitter conflict that erupted several years ago when trawlers first moved into the area, and the small boat fishermen were afraid their fishing grounds would be destroyed. Originally, all the Gulf was ruled off-limits, but, as trawling increased and small boat fishing decreased, the rule has been relaxed a number of times. Permits are now given to a few boats to fish south of the line for exploratory purposes, and one small trawler fished in the Lake in 1964.

In the past, the most powerful control over fishing pressure on the shrimp population has been the relative inefficiency of the gear used. The mandinga is effective in shallow waters but can not be used in deeper waters, and therefore most of the area of Lake Maracaibo is not fished. The Italian trawlers were designed to catch fish and, without modification, their effectiveness as shrimp boats is quite limited. In the last two years, most of these boats have changed over to double-rigged otter-trawls, at great expense. This change has made them quite competitive with the Gulf of Mexico type boats because of their extra horsepower.

5 MARKET

About 6,000 lb (about 2,700 kg) of shrimp (heads-on) are consumed daily in Venezuela, principally in Maracaibo and Caracas. Because of the lack of adequate refrigeration, and because of custom, they are marketed (heads-on) in the same way as fresh fish. Three small canning stations (one in Maracaibo, two in Caracas) process small shrimp for the local market. The vast majority of the production is headed, frozen in 5 lb (2.3 kg) cartons, and shipped to the U.S.A. (Table II). Some heads-on, frozen shrimp are shipped to the European market, principally Spain (Table III). At the present time, U.S. import records are probably the most reliable means of showing Venezuelan production.

With the entrance of Venezuela into the export market in 1960, foreigners and Venezuelans alike hastened to set up processing facilities in order to take advantage of this promising new fishery. By 1962 there existed 27 processing plants, far more than the industry could support. All were small and had little capital reserve to see them through recessions in the international market or times of low production. Most of these processing plants closed down shortly after opening, and only those with efficient management and capital survived. Most of these have grown into modern, efficient, relatively large shrimp processing plants. Today, six plants are in operation in Maracaibo and one in Punto Fijo. The largest has a daily capacity of about 70,000-80,000 lb (32,000-36,000 kg), but seldom works at full capacity.

TABLE II

U.S. imports of shrimp from Venezuela (1951-1956)
(Source: U.S. Bureau Comm. Fish)

Year	Weight (1,000 kg)	Year	Weight (1,000 kg)
1951	0	1959	168
1952	7.3	1960	156
1953	0	1961	1,120
1954	0	1962	2,876
1955	0	1963	2,626
1956	0	1964	3,585
1957	62	1965	5,781
1958	55	1966	1,310

TABLE III

The destination of Venezuelan shrimp exports (Source: Venezuelan Development Ministry)

Destination	1963	1964
U.S.A.	3,328,604 kg	4,185,425 kg
Spain	22,756	77,194
Belgium and Luxemburg	7,000	——
Aruba and Curazao	6,613	3,138
Italy	5,500	——
Western Germany	——	25
Japan	100	——

Most fishermen, both large and small operators, are independent of the processors. This has resulted in a fiercely competitive primary market. The local buyers can outbid the freezing plants and therefore fill up their trucks first; what is left goes to the plants. Since the local consumption is quite steady, the plants are in a much more favorable bargaining position when production is high. Some plants are now buying their own boats, or contracting others, in order to insure a more steady income.

6 SCIENTIFIC INVESTIGATION

In 1957, Milton Lindner made a brief survey of the Maracaibo area and thus became the first biologist to concern himself with Venezuela's shrimp fishery (Lindner, 1957). In 1963, Davant published an illustrated key to the fresh and salt water shrimp of the eastern part of the country; Khandker (1965) made observations on shrimp distribution in lagoons of the same area. The La Salle Foundation (Cervigon, 1965) has conducted exploratory fishing off the Orinoco River Delta. Concerted effort on the scientific investigation of the important shrimp stocks of the country has, however, only recently developed.

In 1963, the Instituto Venezolano de Investigaciones Científicas, with assistance from the University of Miami, and financed by the Fondo Nacional de Investigaciones Agropecuarias, began the first biological study of the shrimp populations that support fisheries in the Gulf of Venezuela and Lake Maracaibo. This work has continued to the present time, and a comprehensive account of investigations up to about two years ago is given by Ewald (1965). The following is a brief resumé of the results of this investigation as it stands today.

Examination of the commercial catch of the area has revealed that it consists of nine species of shrimp (seven penaeid, two caridean), five of these in commercial quantities. They are, in order of importance: Penaeus schmitti Burkenroad , camarón (or langostino) blanco; P. duorarum Burkenroad , camarón rosado; P. aztecus Ives , camarón marrón; P. brasiliensis Latreille , camarón rosado con mancha; Xiphopenaeus kroyeri (Heller), siete barbas; Trachypenaeus similis (Smith) and Sicyonia stimpsoni (Bouvier). Two species of Macrobrachium (M. acanthurus (Wiegmann) and M. amazonicum (Heller)) have been found in commercial catches from the Lake.

In government statistics no distinction is made as to species, and the local market sells all penaeid species as 'camarones' (juvenile penaeids) and 'langostinos' (adult penaeids). For export, the tails are packed as white or brown shrimp, depending on color, which is quite variable. There is, therefore, no manner in which commercial catch records can reveal the relative importance of each species. Efforts have been made to sample the various fishing areas and the analysis of these samples gives an idea of relative importance of different species in different areas (Fig. 1).

In order to understand this distribution, one must have an idea of the physical parameters which might affect it. Lake Maracaibo empties into the Gulf of Venezuela through the Straits of Maracaibo and the Bay of Tablazo. Practically all the fresh water for the system comes from the southwest area of the Lake, where rainfall reaches 180 cm/year and where lush rain forests abound. The northern part of the system is arid and barren, with a maximum rainfall of less than 30 cm/year. The Lake itself has a fairly uniform superficial salinity of approximately 4.0‰. Since 1957 (which marks the opening of the ship channel) there has been an alarming increase in salt water intrusion into the Lake. In the Bay and the Straits the salinity ranges from about 4‰ in the south to about 26‰ at the entrance to the Gulf. The Gulf is divided into two parts by a sill in depth running north to south from Punta Espada to slightly west of Punta Campana. To the west of this sill the 'Ensenada de Calabozo' reaches 27 m in depth, and to the east the 'Outer Gulf' gradually drops to a depth of 80 at its entrance. The Ensenada de Calabozo is greatly affected by the fresh water outflow of the Lake. The clockwise, trade-wind-driven circulation of the Gulf pushes the outflow into this part of the Gulf and salinities range from 26‰ in the south to 32‰ at the edge of the sill. At the sill there is much mixing and beyond it sea water salinities are found. Hyper-

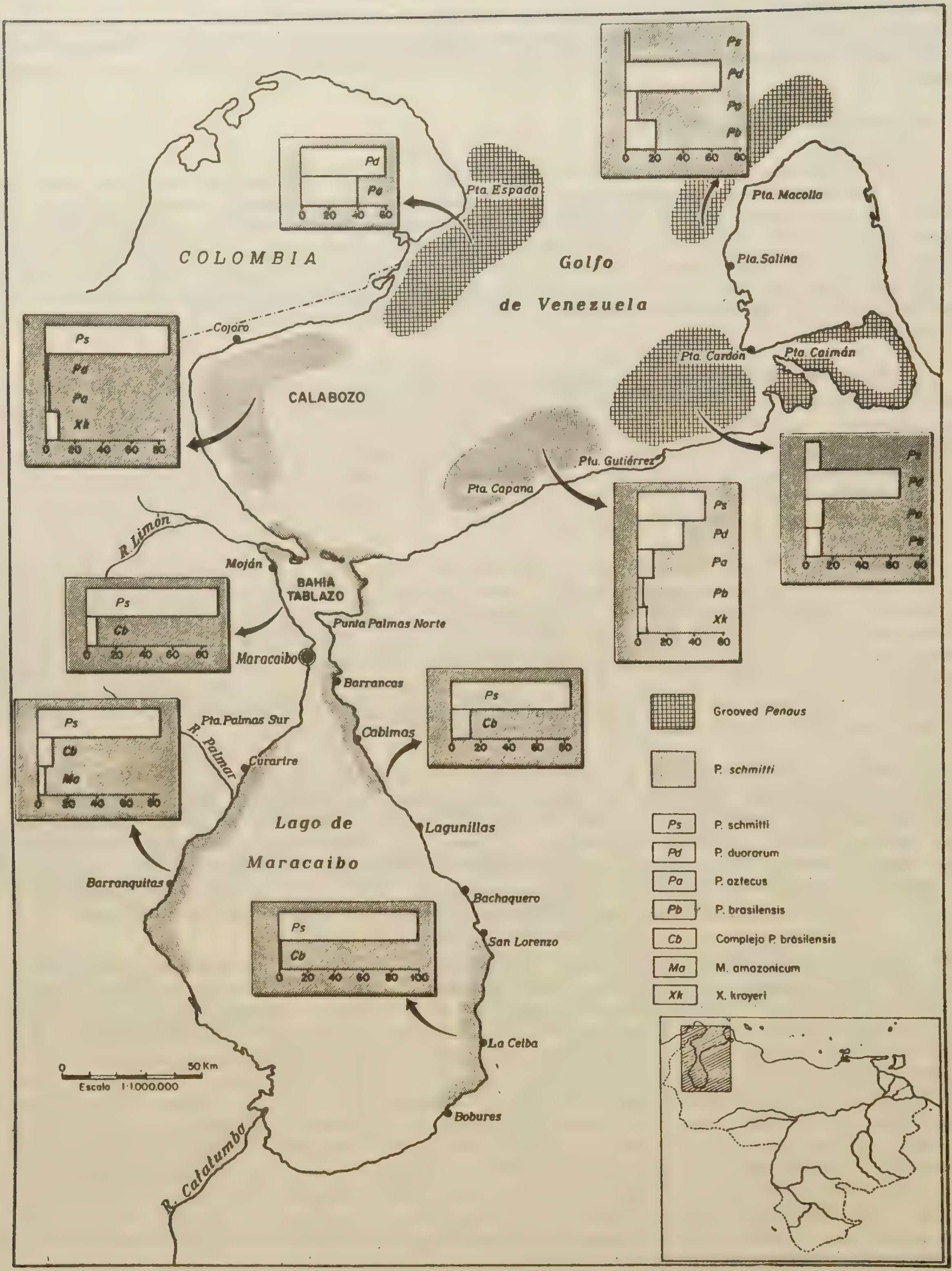
COLOMBIA
Golfo
de Venezuela
Pta. Espada
Pta. Macolla
Pta. Salina
Pta. Cardón
Pta. Caimán
Cojoro
CALABOZO
Pta. Gutiérrez
Pta. Capana
R. Limón
Moján
BAHIA TABLAZO
Punta Palmas Norte
Maracaibo
Barrancas
Cabimas
Pta. Palmas Sur
R. Palmar
Curarire
Lago de
Maracaibo
Lagunillas
Barranquitas
Bachaquero
San Lorenzo
La Ceiba
Bobures
R. Catatumbo
0
50 Km
Escala 1:1.000.000
Ps
Pd
Pa
Pb
Cb
Ma
Xk
0
20
40
60
80
100
Grooved Penaus
P. schmitti
Ps P. schmitti
Pd P. duorarum
Pa P. aztecus
Pb P. brasilensis
Cb Complejo P. brasilensis
Ma M. amazonicum
Xk X. kroyeri

Fig. 1 Percentage species composition of commercial catch for different areas of the Gulf of Venezuela and Lake Maracaibo.

saline waters are frequently found in the southeastern Outer Gulf, especially in the Golfete de Coro. This is a very effective evaporation basin with its high velocity trade winds, slight rainfall and high year-round temperatures.

Shrimp distribution is clearly affected by this salinity distribution. Fig. 1 graphically presents data obtained from samplings taken during 1964 and 1965 and shows the relative numbers of each species (males and females), expressed as percentages. Unfortunately, this does not show seasonal trends, but this aspect is being studied.

P. schmitti is dominant (as juveniles) in the Lake and (as adults) in the Ensenada de Calabozo. In 1965 this species accounted for more than half of the production. The species is fished year-round, but maximum production occurs during March, April and May in the Gulf, and during the latter half of the year in the Lake. Information from histological examinations of gonads, size distributions, and a survey of larvae and postlarvae, have established that spawning takes place on the northwestern edge of Calabozo, in waters of 20-26 m in depth, and that the shallow waters of the Lake and Bay of Tablazo are the principal nursery areas for the species. In October and November 1966, fairly large numbers of P. aztecus were found in the northern part of the Lake and in the Bay. As the salinity in the Lake increases there appears to be a deeper penetration of P. schmitti into the southern parts and an invasion of P. azteous into the northern part. P. duorarum is dominant in the catches in the Outer Gulf. Some sampling has been undertaken in the Golfete de Coro, where small P. duorarum and X. kroyeri were taken. P. brasiliensis and P. aztecus have been found in the samples, at times in large numbers, but their distribution is inadequately known.

Because of the large area involved and limited resources available, for the past year and a half efforts have been concentrated on a thorough study of P. schmitti. This currently involves a tagging program which is designed to define migration routes and growth rates. Information thus recently obtained will be published shortly.

In 1968 a UNDP/Special Fund project will begin in Venezuela, and considerable effort will be made to increase all branches of fishery research, including shrimp investigations.

7 PROBLEMS THAT CONFRONT INDUSTRY

Several important problems confront the industry and it is these that have made both the industry and government aware of the necessity for information on the biology and dynamics of the populations that support the fishery.

It is being proposed that the entrance to the Lake (The Bay of Tablazo) be enclosed by a system of dikes to prevent further intrusion of seawater and to correct a problem of sedimentation that currently exists in the ship channel. How will these structures affect shrimp migration? Will resultant lower salinities in the Bay and Gulf eliminate access to certain nursery areas?

The explosive development of the shrimp industry in western Venezuela has meant a rapid increase in fishing effort. There are plans to at least double the present fleet. How many more trawlers can be brought in?

In 1965 the Venezuelan shrimp industry was in its glory. A total production of twice the amount of the previous year had placed the country just behind Mexico and India in shrimp exports to the U.S.A. Plants were working full-time, local prices were cheap and the world market quite favorable. Plants were making rapid plans for expansion, new trawlers were ordered. Then, production began to drop, but people were unconcerned until the spring run of white shrimp failed to materialize. Brown and pink shrimp production was also lower than usual that year and production for the first nine months of 1966 was only 18 percent of that of the corresponding period of the year before. Disaster hit the plants, which had only recently installed new freezer capacity, and the enlarged trawler fleet. The Lake fishery was also greatly reduced.

Did overfishing have something to do with the scarcity of shrimp? Was the increased salinity in the Lake affecting the nursery areas?

Questions like these are frequently very difficult to answer. With the little amount of information we have at present on this fishery, we cannot begin to answer them; we can only make educated guesses.

Venezuela has a valuable resource in its shrimp fishery. The biologist can contribute a great deal towards the understanding of this resource if he has sufficient funds, if he obtains adequate assistance from the industry and government and if he has time at his disposal. Present plans should guarantee such conditions, and as understanding of the biology of the shrimp populations increases, biologists should be better able to assist those involved in the rational exploitation of those populations.

Meanwhile, the industry remains optimistic. Last year's drop in production has weeded out most of the inefficient operators and forced others to reduce their costs by modernization. Fortunately, the fishery is not dependent on one species alone, but three. In the early months of 1967, white shrimp have shown only slight improvement over 1966, but pink and brown shrimp are keeping most plants operating full-time at present.

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PREDICTING BROWN SHRIMP ABUNDANCE IN THE NORTHWESTERN GULF OF MEXICO [1]

by

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Abstract

Studies of the feasibility of predicting the size of annual crops of brown shrimp (*Penaeus aztecus*) have been underway since the early sixties at the Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas. They are based on the premise that the relative abundance of postlarval or juvenile shrimp is indicative of subsequent commercial supplies. The present paper reviews the development of these studies, discusses sampling problems in measuring postlarval abundance, and correlates abundance indices between life history stages. Analyses of landing statistics indicate that predictions of brown shrimp abundance may be applicable to broad geographic areas of the Gulf of Mexico.

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[1] Contribution No.238 from the Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas

E/42

PREVISION DE L'ABONDANCE DES CREVETTES Penaeus aztecus DANS LE NORD-OUEST DU GOLFE DU MEXIQUE

Résumé

Depuis le début des années 60, le Laboratoire de biologie du Bureau des pêches commerciales de Galveston (Texas) étudie la possibilité de prévoir l'ampleur des captures annuelles de Penaeus aztecus, en se fondant sur l'hypothèse selon laquelle l'abondance relative des stades postlarvaires ou juvéniles de cette crevette fournit un indice des disponibilités ultérieures pour la pêche commerciale. La communication traite des progrès réalisés au cours de ces études, examine les problèmes d'échantillonnage associés à la mesure de l'abondance des postlarves, et met en corrélation les indices d'abondance à divers stades du cycle biologique. L'analyse des statistiques des apports fait penser que les méthodes de prévision de l'abondance de P. aztecus pourraient valoir pour de larges zones géographiques du golfe du Mexique.

PRONOSTICO SOBRE LA ABUNDANCIA DE PENAEUS AZTECUS AL NOROESTE DEL GOLFO DE MEXICO

Extracto

En el Laboratorio Biológico de la Oficina de Pesca Comercial de Galveston, Texas, se han llevado a cabo desde principios de 1960 investigaciones para averiguar la posibilidad de predecir la magnitud de las cosechas de camarón marrón (Penaeus azteous). Tales estudios se basan en el supuesto de que la abundancia relativa de camarón, en su fase postlarval o juvenil constituye un índice de las posteriores disponibilidades comerciales. En este ensayo se examina el desarrollo de estos estudios, se discuten los problemas de muestreo que implica la medición de la abundancia de ejemplares en fase postlarval y se ponen en relación los índices de abundancia entre las distintas fases del ciclo vital. Los análisis de las estadísticas de desembarque indican que los pronósticos sobre la abundancia de camarón marrón se pueden aplicar a amplias zonas geográficas del Golfo de México.

1 INTRODUCTION

Biologists at the Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas began studies in the early sixties to investigate possibilities of predicting the annual abundance of brown shrimp (Penaeus aztecus Ives). This work was based on the premise that the number of postlarval shrimp collected during their movement from the Gulf to coastal bays and the density of juvenile shrimp in estuarine areas bear a proportional relation to subsequent commercial supplies. Several other groups of biologists, working under contract with our laboratory or independently, have pursued the same approach along various parts of the Gulf and south Atlantic coasts. A sizable number of general references to these studies have appeared in annual reports of the laboratory at Galveston, in Commercial Fisheries Review and in Louisiana Conservationist. More detailed reports include those of Baxter (1963), Baxter and Renfro (1967), Christmas, Gunter and Musgrave (1966), Louisiana Wild Life and Fisheries Commission (1964), St. Amant, Corkum and Broom (1963), and St. Amant, Broom and Ford (1966).

The present paper provides a review of studies on shrimp prediction underway at the Biological Laboratory in Galveston. It demonstrates the possibilities and limitations of current approaches to the problem so that others may benefit from our experiences.

2 SOURCES OF DATA

Possible approaches to predicting shrimp abundance are limited because little is known about factors that influence the size of the populations. Without this information, we can seek a correlation only between measures of abundance at two life history stages and base predictions on the earlier measure. Fortunately, brown shrimp pass through reasonably distinct stages and it is possible to follow the development of a brood for several months. Spawning takes place in offshore oceanic waters and the young shrimp enter estuaries as postlarvae. After a period of rapid growth to a total length (tip of rostrum to end of telson) of 50 to 120 mm, they return offshore to depths of 30 to 80 m. The shrimp are fished commercially during both the estuarine and oceanic portions of their life if local conditions and statutes permit.

2.1 Postlarvae

A small-scale study to investigate seasonal changes in the movement of postlarval shrimp through the principal entrance to Galveston Bay began in November 1959 as part of an expanding shrimp research program. Collections of organisms near the shoreline of the entrance were made twice each week with the 1.5-m hand-drawn beam trawl described by Renfro (1963). Tows were made alternately in the morning and afternoon in an effort to sample during both ebb and flood tides each week. Penaeid shrimp were separated from the catch, identified, and counted at the laboratory. Details of sampling procedures and species identification were provided by Baxter (1963) and Baxter and Renfro (1967). Sampling was interrupted in May 1961 because of the pressing needs of other projects.

The significance of the catch data on postlarvae gathered between November 1959 and May 1961 became apparent shortly after sampling was suspended. Comparatively high numbers of postlarvae were caught in the early spring of 1960 and were followed by near record catches of brown shrimp in the commercial fishery during summer months. In 1961, our catches of postlarvae were small as were later commercial harvests, suggesting that catch data on postlarvae were indicative of brown shrimp abundance.

Semiweekly sampling for postlarvae was resumed in August 1961 with a new objective - to investigate the feasibility of predicting the relative abundance of commercial shrimp from catches of postlarvae. Sampling procedures were not changed because we anticipated that a simple and inexpensive technique for predicting would be more acceptable to agencies responsible for shrimp management than would complex sampling schemes. With the exception of a brief interruption caused by Hurricane Carla in September 1961, a routine schedule of sampling has been followed to the present. The location of the four stations at which collections were obtained is shown in Fig. 1.

2.2 Juvenile shrimp

Within 6 to 12 weeks after they enter estuaries, young shrimp grow to a size (70 to 100 mm in total length) that is favored by sport fishermen as bait. A seasonal bait shrimp fishery has developed in Galveston Bay during recent years to supply this market. Shrimp are harvested with otter trawls towed by skiffs or small trawlers and then distributed to dealers who sell them to sport fishermen (Inglis and Chin, 1966).

A continuing survey of the bait shrimp fishery of Galveston Bay began in 1957; its early results, including data on landings and species composition, were reported by Chin (1960). Since June 1959, statistics of fishing effort also have been gathered on a weekly schedule. The survey procedure requires that interviews be obtained from at least half of the bait shrimp dealers and fishermen in the bay area each week, and a visual check is made of other bait shrimp stands to determine how many are open for business. From this information, total landings and fishing effort are estimated. Species and size composition of landings are assessed from samples of shrimp purchased weekly from a random selection of dealers.

2.3 Adult shrimp

All shrimp landed by the commercial fishery and sold for human consumption are here classed as adults, whereas those taken by the bait fishery are considered to be juveniles. This distinction is based on the source of landing data rather than the stage of maturity of the shrimp. The classification is valid as it pertains to bait shrimp but is arbitrary as applied to commercial landings. The latter consist of a large range of sizes that by Renfro's (1964) definitions would be classed as juvenile, subadult, and adult shrimp.

Landing data for the commercial fishery are available in monthly tabulations published by the Fish and Wildlife Service in the Current Fishery Statistics series under the title Gulf Coast Shrimp Data. A description of these tabulations and of survey procedures used in gathering the data was given by Kutkuhn (1962). Data are grouped according to species and size composition of landings as well as depth and location from which catches originate. The geographic areas and coded subareas to which information on catches is assigned as it is obtained are outlined in Fig. 2. The data of interest in the present study are those pertaining to subarea 18 and adjacent inshore waters of Galveston Bay.

3 MEASURES OF ABUNDANCE

Predictions of the relative size of adult shrimp stocks from samples of postlarvae or juveniles require an index of abundance at these life history stages and definitions of the relation between indices. The reliability of forecasts will depend on the accuracy and precision of the measures of abundance, provided that mortalities between stages do not depart greatly from the average.

3.1 Postlarvae

3.1.1 Postlarvae of significance to later harvests Our data, in the form of postlarval catches, bait shrimp landings and commercial harvests, indicate that the bulk of the brown shrimp crop develops from postlarvae that enter estuaries between early February and the end of May. Attempts to identify more exactly the group of postlarvae that best indicates later harvests are hampered, however, by seasonal and annual variation among our sample data. Counts of brown shrimp postlarvae from each collection made from February through May of 1960-66 are listed in Table I. Catches made in 1960 and 1961 appear to vary more among collection dates than those of later years, but part of the variation may have resulted from the change in location of the sampling site (from station 1 to station 2) in the latter part of 1961 (Fig. 1).

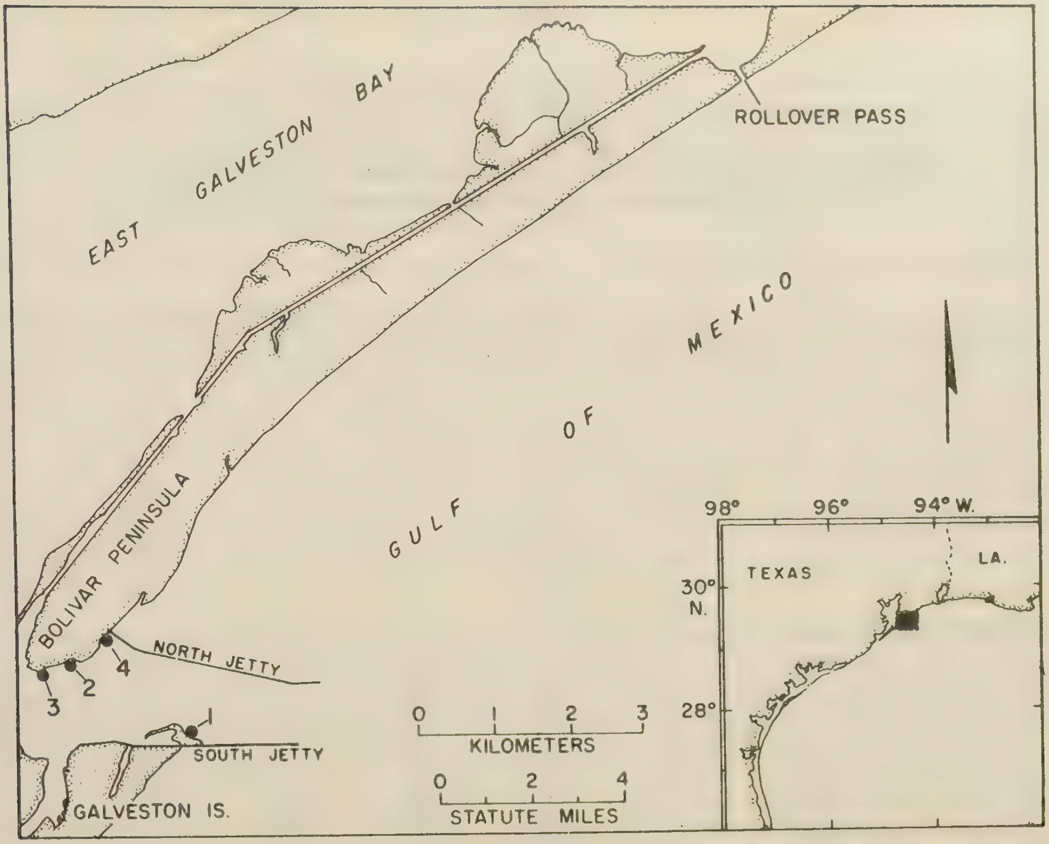
EAST GALVESTON BAY
ROLLOVER PASS
GULF OF MEXICO
BOLIVAR PENINSULA
NORTH JETTY
SOUTH JETTY
GALVESTON IS.
1
2
3
4
0 1 2 3
KILOMETERS
0 2 4
STATUTE MILES
98° 96° 94° W.
30° N.
28°
TEXAS
LA.

Fig. 1 Locations of stations at which postlarval shrimp have been collected on a routine basis (after Baxter, 1963). Periods during which samples were taken at the different stations were: station 1, November 1959–September 1961; station 2, September 1961–November 1961; station 3, June and July 1962; and station 4, November 1961 to date.

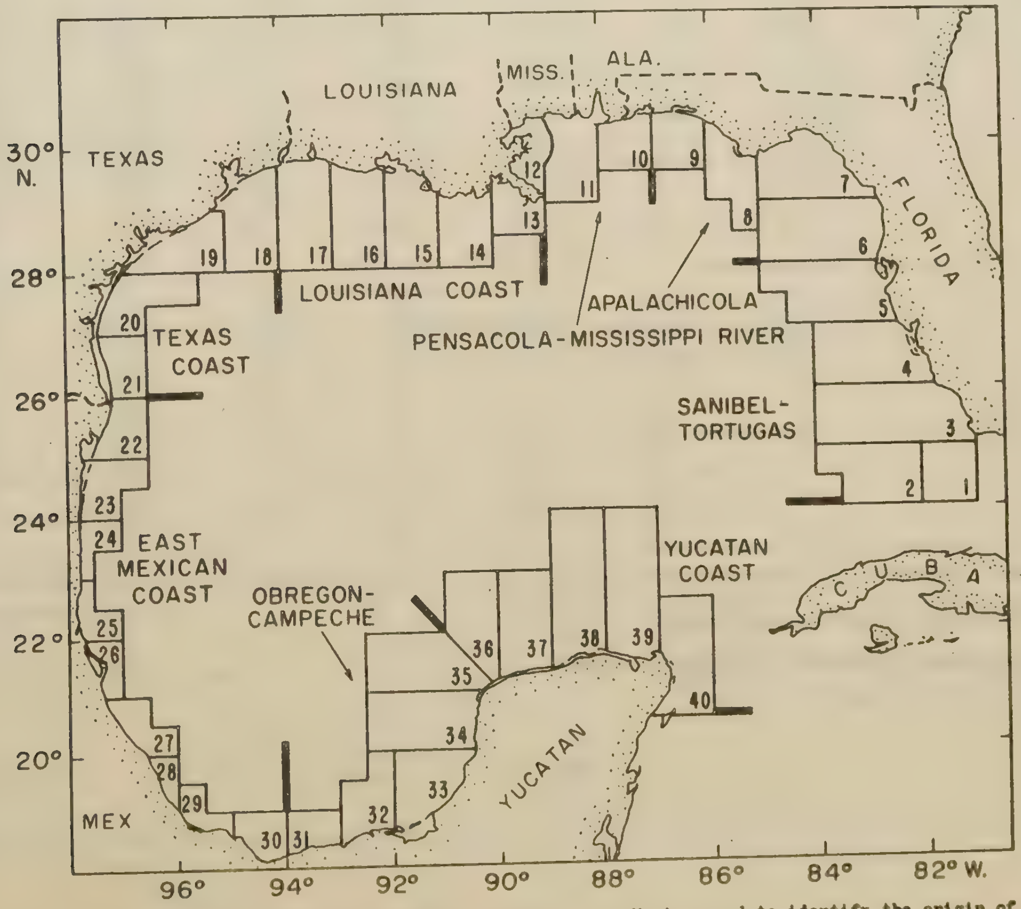
LOUISIANA
MISS.
ALA.
TEXAS
FLORIDA
LOUISIANA COAST
TEXAS COAST
APALACHICOLA
PENSACOLA-MISSISSIPPI RIVER
SANIBEL-TORTUGAS
EAST MEXICAN COAST
OBREGON-CAMPECHE
YUCATAN COAST
YUCATAN
CUBA
MEX
30° N.
28°
26°
24°
22°
20°
96° 94° 92° 90° 88° 86° 84° 82° W.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

Fig. 2 Geographic areas and subareas in the Gulf of Mexico used to identify the origin of shrimp landings (after Kutkuhn, 1962).

TABLE I

Counts of postlarval brown shrimp caught in semiweekly collections in February, March, April and May, 1960-66

Month	1960	1961	1962	1963	1964	1965	1966
February	1	0	1	0	0	51	0
	0	0	73	0	2	16	0
	2	0	34	0	0	16	4
	0	1/	196	0	14	143	5
	3	4	48	0	3	142	591
	3	0	222	0	0	249	3
	2	0	53	0	0	120	22
	2	1/	1,220	0	0	77	57
March	0	6	0	441	0	24	32
	0	5	40	16	3	13	51
	6	2	368	288	26	50	526
	53	1	66	21	46	612	83
	39	97	8	280	215	198	427
	72	28	506	286	765	30	117
	39	1/	526	986	246	416	312
	1/	2	140	114	110	38	206
	4,710	42	75	2/	583	136	67
April	3,680	6	1,682	360	399	193	107
	86	12	234	3,521	383	48	369
	5	4	24	147	117	498	434
	1,000	1/	135	54	432	187	749
	100	209	192	167	160	250	423
	9	10	44	44	38	205	264
	50	3	103	103	8	105	116
	56	2	3	93	64	142	24
	3	2/	2/	41	2/	313	40
May	0	51	4	68	58	88	84
	4	1/	250	181	294	67	24
	6	889	23	71	60	178	8
	1	1/	7	10	19	160	2.
	2	1/	2	16	31	213	18
	9	1/	0	17	579	39	8
	7	1/	0	134	4	47	10
	5	1/	0	29	89	212	11
	0	1/	3	28	9	2/	1

1/ Scheduled sample not taken

2/ No entry because of 4-week month

In most years, the largest numbers of postlarvae were taken in March and April, but abundance within these months seems to follow no regular trend. Collections made in February differ considerably from year to year, ranging from no postlarvae to relatively large numbers. Those from May appear to reflect a decline from the March-April peak, but differences between years are great. Because of the lack of a consistent pattern in these data, our decision on samples to include in an index had to be largely subjective.

3.1.2 Sampling variability Barnes (1952) and others have shown that counts from catches of marine organisms do not necessarily conform to a normal distribution and that the original data often must be transformed before standard statistical tests are employed. A proportional relation between the standard deviation and the mean of sample catches indicates that a logarithmic transformation is appropriate (Fig. 3). The transformation eliminates the relation (Fig. 3) and causes this type of data to follow a normal distribution more closely (Fig. 4). More meaningful estimates of the sample mean or variance can be obtained from transformed data than from the original sample counts. For this reason, our counts of postlarvae were converted to logarithms before analysis and sample averages are reported as geometric rather than arithmetic means.

Special studies were started in the spring of 1963 to investigate the influence of several potential sources of sampling variability. In particular, we wanted to determine the reliability of our sampling gear, the effects of tides on postlarval catches, and the possibility of diel differences in the availability of postlarvae to our net. From March through August, three samples rather than one were taken on regular semiweekly collection dates. Also, three concurrent samples were obtained at 2-h intervals over a 4-day period in early April. These two sets of data, each consisting of 48 replicated observations, provided considerable insight into the sampling problems.

The results of an analysis of variance of each set of replicated samples (Tables II and III) constitute tests of the performance of the beam trawl. Variations between sampling times was significantly greater than between replicates. Results were surprisingly similar for the two groups of data and, for each set, only 2 percent of the total variation was due to differences among replicates. This information assured us that the beam trawl provides a satisfactory sample in the postlarvae present in the vicinity of our sampling site. It also showed that the total variation of samples taken over a period of 4 days was almost as great as that from collections made during 6 months - a result of the fact that the range in numbers of postlarvae at a given location can change from zero to several thousand within a few hours.

TABLE II

Analysis of variance of replicated samples of postlarvae caught at 2-hour intervals over a 4-day period

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Between times	47	39.9914	0.8509	76.7
Between replicates	96	1.0666	0.0111	Table value at the 0.01 level = 1.73
Total	143	41.0580		

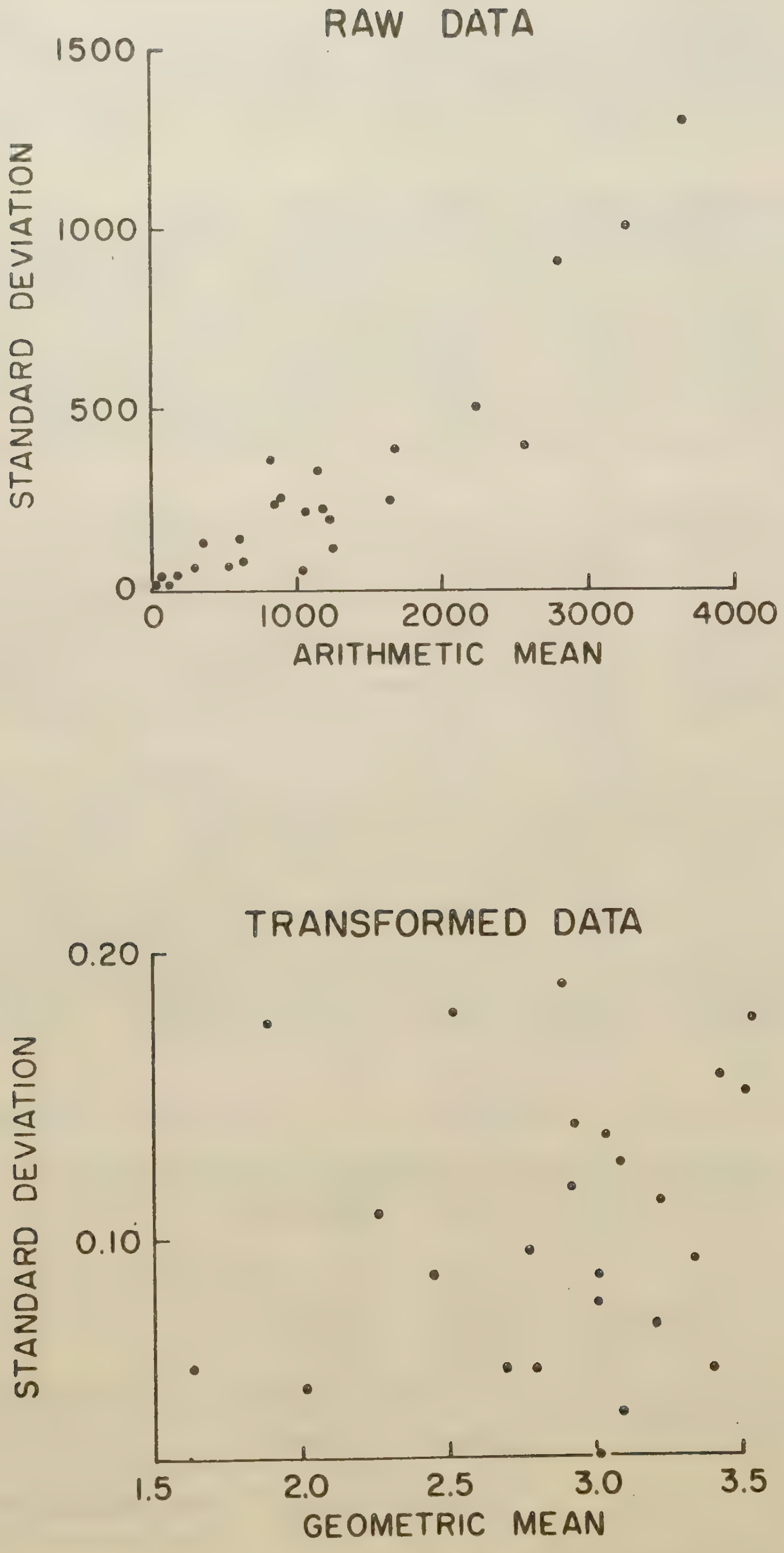

Fig. 3 Relation between the standard deviation and the mean of a selected group of postlarval shrimp catches made in 1963.

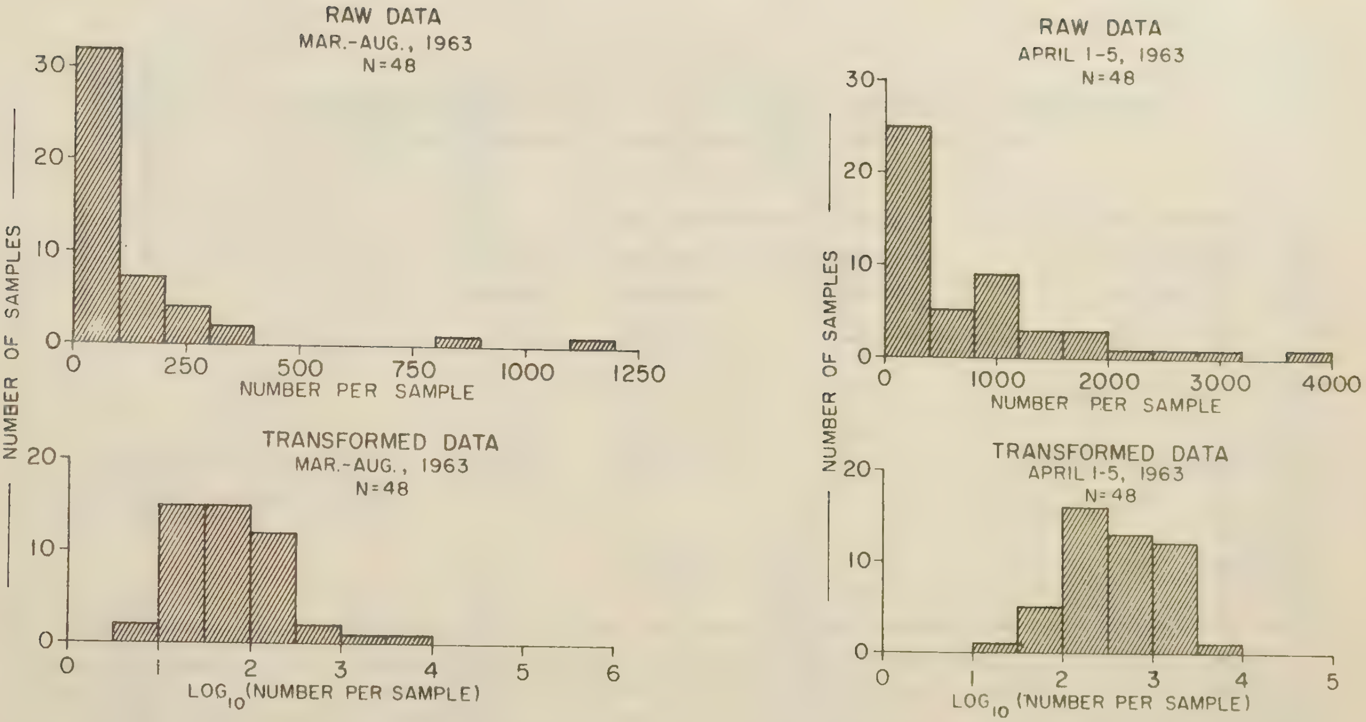

Fig. 4 Frequency distributions of numbers of postlarvae in samples (N) illustrating an effect of the logarithmic transformation. One catch was too large (3,286) to be shown in the upper left-hand graph.

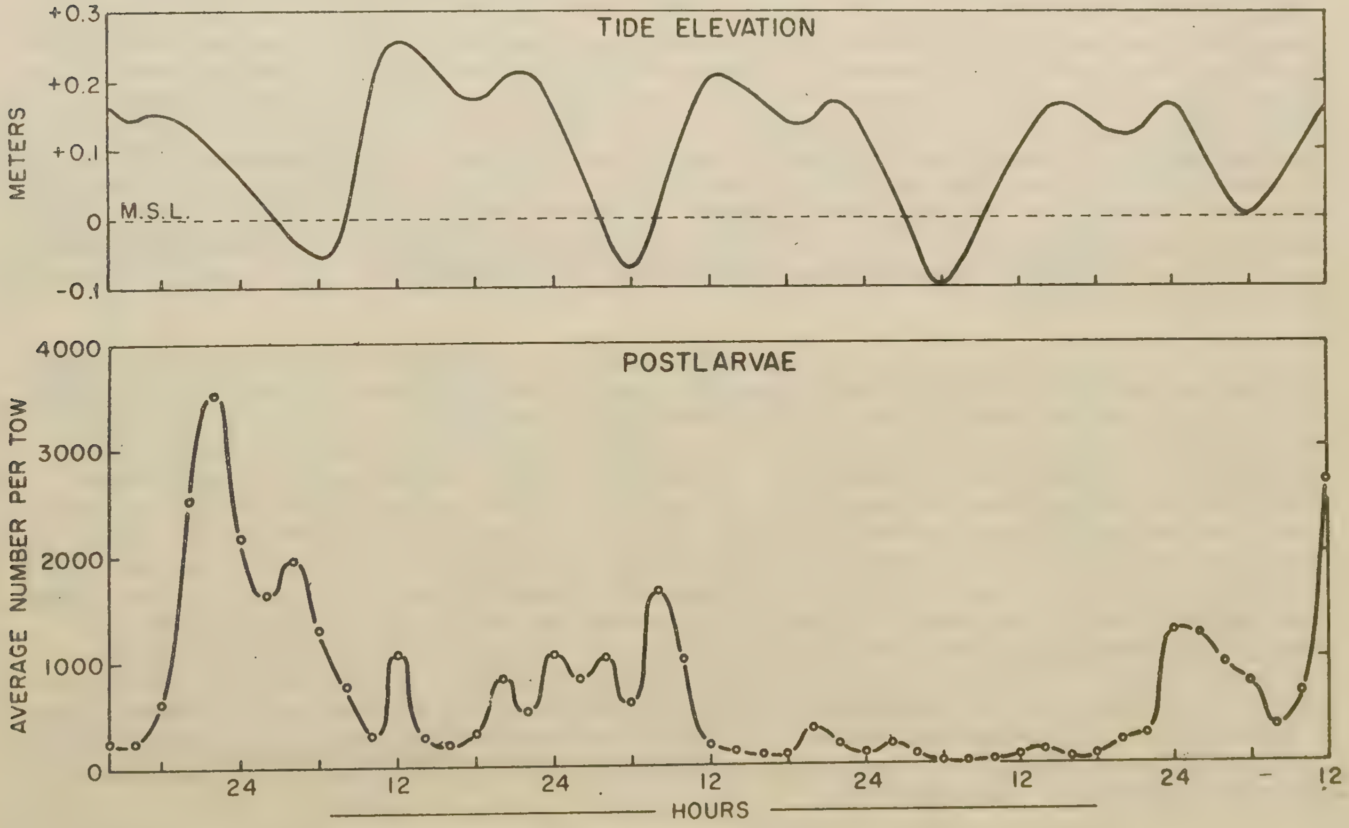

Fig. 5 Catches of postlarvae and tide elevation at the regular sampling site in the entrance to Galveston Bay, 1-5 April 1963.

TABLE III

Analysis of variance of replicated samples of postlarvae caught at 3-to 5-day intervals over a 6-month period

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Between times	47	48.4585	1.0310	44.7
Between replicates	96	2.2156	0.0231	Table value at the 0.01 level = 1.73
Total	143	50.6741		

The collections made at 2-h intervals in April 1963 provided no obvious answers to questions concerning the effects of tides or diel differences in the availability of postlarvae (Fig. 5). Similar collections made at the same site in March 1964 also showed no apparent correlations. We concluded that our sampling station was probably in a position where water movements differed from recorded tide levels. To pursue the problem further, we made hourly collections of postlarvae and measurements of water movements over two 3-day periods in the spring of 1965 at Rollover Pass, a narrow, secondary inlet to Galveston Bay (see Fig. 1). Because of fast water currents at this pass, samples were taken with a 0.5-m plankton net suspended from a bridge rather than with the beam trawl. The number of postlarvae caught varied with water movements, at least when currents were strong (Fig. 6). Presumably, specimens caught during ebb tides were those that had been carried into the bay on a previous flood tide. If postlarvae are also transported through the principal entrance to Galveston Bay by water currents, it follows that any of a number of conditions that affect the direction and velocity of the flow of water can likewise influence the numbers of postlarvae carried past our sampling station. Included among these conditions may be normal tidal changes, storms with their accompanying wind-driven water movements, and excessive amounts of runoff from land.

3.1.3 Indices of abundance The number of combinations of data that might be used to calculate an abundance index for postlarvae is almost unlimited. Baxter (1963) used the arithmetic mean of the number of brown shrimp postlarvae in collections made from February through May. Christmas, Gunter and Musgrave (1966), who made their observations in Mississippi Sound, used the average catch of postlarval brown shrimp taken from February through July. The most appropriate method of combining data on postlarvae to form an index is open to question. The decision should be based on knowledge of the sampling distribution of counts of postlarvae, but our data are not sufficient to permit a definite choice. Conceivably, the distribution of numbers of postlarvae per sample might form a normal curve if enough collections were made during periods of peak abundance. If so, an index should be formed from an arithmetic mean. The small number of our collections make it advisable to transform counts of postlarvae to logarithms in order that they will approximate a normal curve. A geometric mean is then appropriate for an index number. It should be emphasized, however, that the method of combining data to form an index is much less important than the quality of data included.

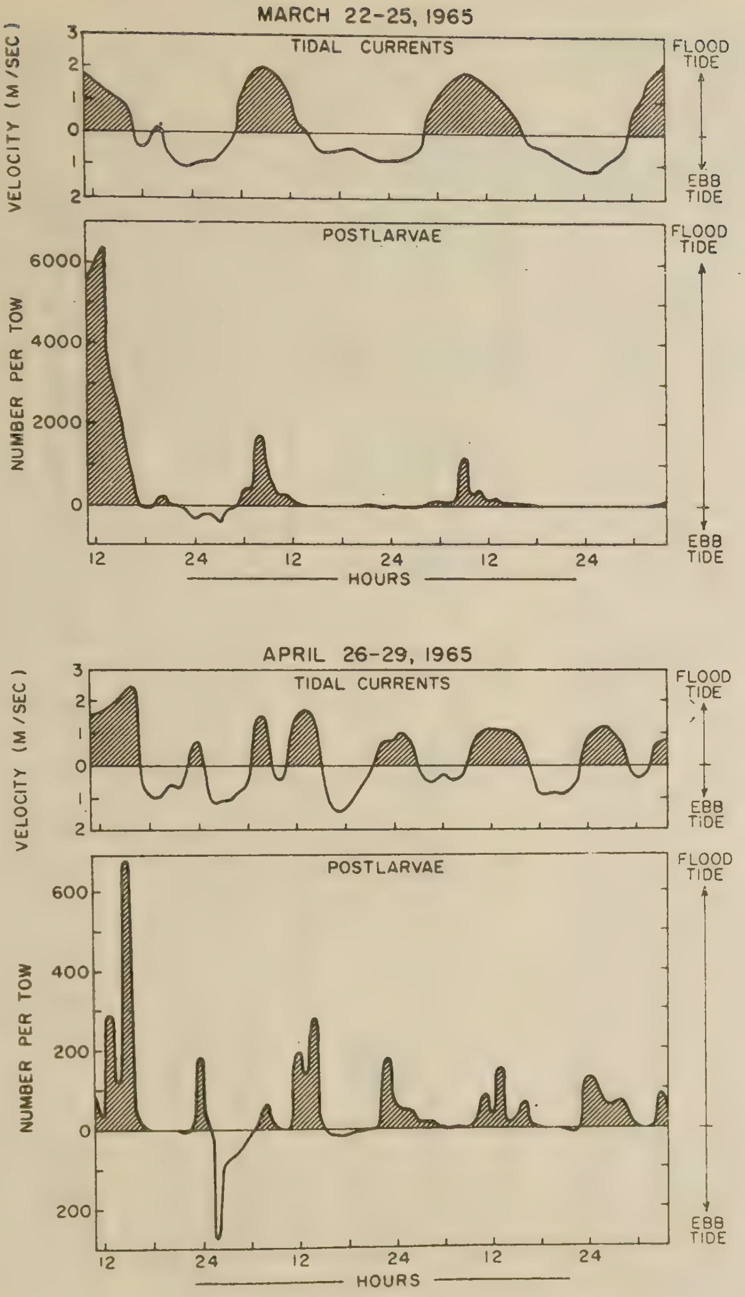

Fig. 6 Relation of catches of postlarvae to tidal currents at Rollover Pass, a relatively narrow inlet to Galveston Bay. Shaded areas indicate water or postlarvae moving into the bay.

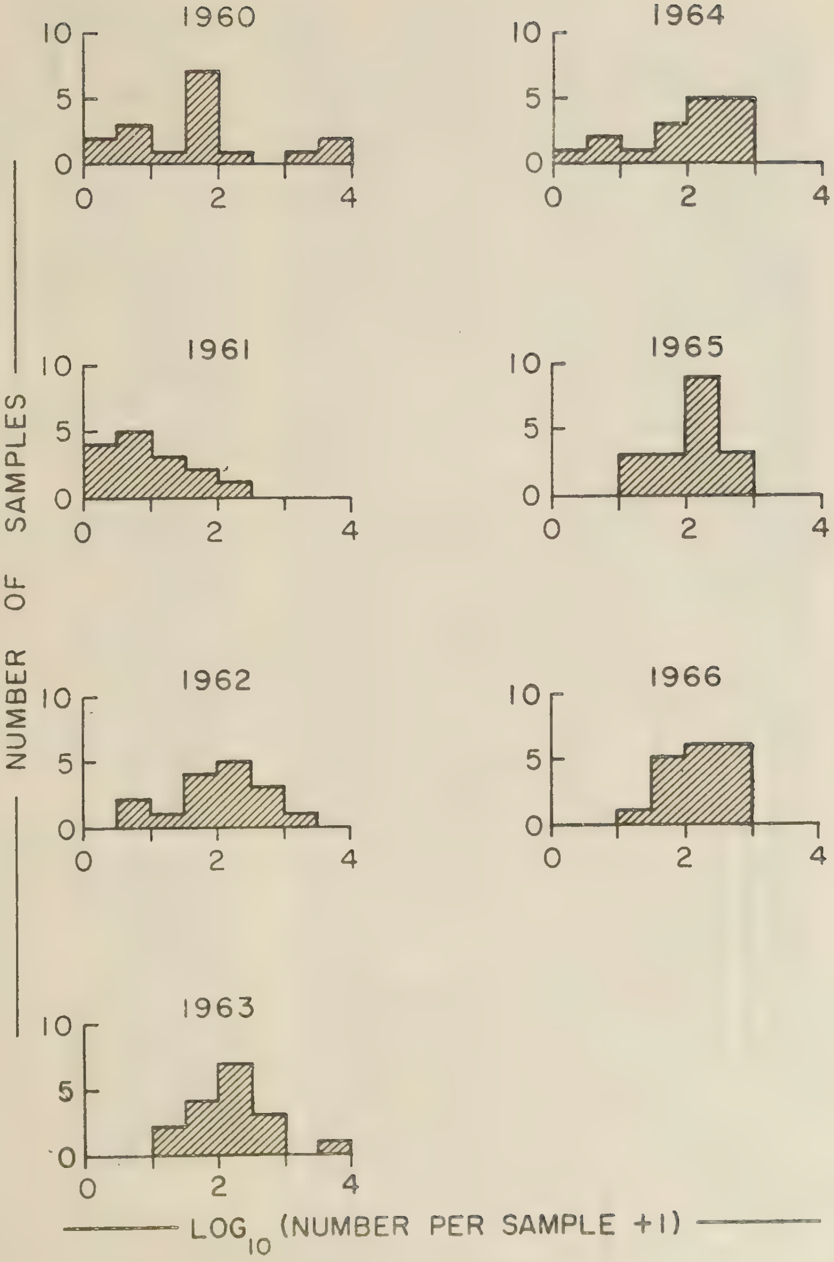

Fig. 7 Distributions of counts of brown shrimp postlarvae collected in March and April 1960-66.

Distributions of counts of postlarvae collected in March and April 1960-66 are presented in Fig. 7. Collections represented in this figure and listed in Table I are those from which we might logically expect to develop an index to the commercial stock of brown shrimp making its appearance in July and August. The shapes or midpoints of these distributions change little if samples from February or May are included. Without resorting to calculations, it is evident that the means of the distribution are fairly similar for all years except 1961. This uniformity implies that postlarval brown shrimp stocks were of the same general magnitude in most of these years - a situation that is not supported by data from the bait and commercial fisheries.

A series of geometric and arithmetic index numbers are provided in Table IV. Also listed, for comparison, are estimates of the relative size of brown shrimp stocks in Galveston Bay in the early summers of 1960-66. The latter were derived from data on bait shrimp landings and are discussed in more detail in a subsequent section. In general, poor correlations exist between the indices of abundance of postlarvae and bait shrimp. We have greater confidence in the indices based on bait shrimp catches and believe that reliable measures of postlarvae will require changes in past sampling procedures.

TABLE IV

Index numbers (average number per sample) based on catches of brown shrimp postlarvae in the spring months of 1960-66

Indices	1960	1961	1962	1963	1964	1965	1966
Geometric means							
March-April	41	9	77	152	82	120	155
March-May	17	14	30	96	68	115	64
February-May	11	6	37	32	29	103	41
Arithmetic means							
March-April	583	29	250	410	211	192	242
March-May	382	81	174	287	182	172	167
February-May	293	57	188	219	140	155	148
Best estimate of relative population size[1]	56	26	29	37	27	42	19[2]

[1] Based on catch per unit of effort by the Galveston Bay bait shrimp fishery, 25 April - 31 July.

[2] We believe that this estimate is biased and that it should have been about 32.

3.1.4 Plans for the future Experience to date has identified several sources of variation that can affect an index of postlarval abundance and provides a base from which to plan future investigations. An apparent shortcoming of past data is the small number of samples obtained during period of peak postlarval movements. We are considering three ways of increasing the frequency of sampling and thereby reducing the variability of an index:

(i) Collect postlarvae by present methods, but increase the number of collections by a factor of at least 5, or preferably, 10. This change would give 10 or 20 samples each week during periods when peak numbers of brown shrimp are entering Galveston Bay. If a new station were located where the relation between the numbers of postlarvae in samples and tidal movements is clear-cut fewer samples might suffice. The expense of this approach in terms of the time and manpower needed for sampling could easily become prohibitive, however.

(ii) Attempt to minimize the influence of environmental variables, especially tidal influences, on catches by establishing a collection site seaward of the entrance to the bay. Although fewer samples might be required, the cost per sample would increase and new sampling techniques would have to be developed.

(iii) Install a mechanical sampling device that takes small samples at frequent intervals or continuously at a convenient location in the entrance to the bay. The advantage gained by continuous sampling is that a large proportion, essentially all, of the variation caused by environmental factors can be considered as random. If the device were placed in a location where a nearly constant proportion of the entering postlarval shrimp passes, the reliability of an index would depend principally on the efficiency of the gear.

The feasibility of investing money in the development and maintenance of more expensive sampling gear depends on the ultimate value of predictions. It is impossible to estimate their worth because we have no way of judging how they might affect operations of the fishery. Presumably, advance information regarding shrimp abundance would enable various elements of the shrimp industry to reduce costs and perhaps divert efforts when poor harvests are expected or to expand facilities and clear distribution channels for good harvests. The benefits of these procedures would be relatively small in their application to the fishery in the Galveston area, but could be substantial if applied to the entire Gulf of Mexico shrimp industry and its supporting services. Relatively few postlarval sampling stations might serve wide areas of the Gulf because trends in the abundance of a species of shrimp may be similar over wide geographic areas. This consistency in trends is explored further in a later section.

3.2 Juvenile shrimp

The relative size of shrimp stocks in Galveston Bay is reflected better by landings of the bait shrimp fishery than by our catches of postlarvae. This fishery yields information that otherwise could be obtained only through an extensive and costly program of field sampling. As suggested by the home locations of bait shrimp dealers and boats in Fig. 8, the operations of the fishery cover most peripheral areas of Galveston Bay.

Time is important when we consider predicting the size of commercial stocks from statistics of the bait fishery. Brown shrimp are most abundant in bait landings from Galveston Bay during May, June, and July. Offshore commercial fishing for young-of-the-year brown shrimp begins in late June and reaches peak intensity in July or August. Useful predictions must be based on early season catch data from the bait fishery.

The brown shrimp stock of principal interest for predictions may be defined as that represented by bait fishery landings from 25 April to 31 July. These dates are arbitrary but cover most of each year's brown shrimp stock in the bay and probably include most of the shrimp that appear as postlarvae in March, April, and May. The earliest catches of brown shrimp by the bait fishery are expected about 25 April, and the

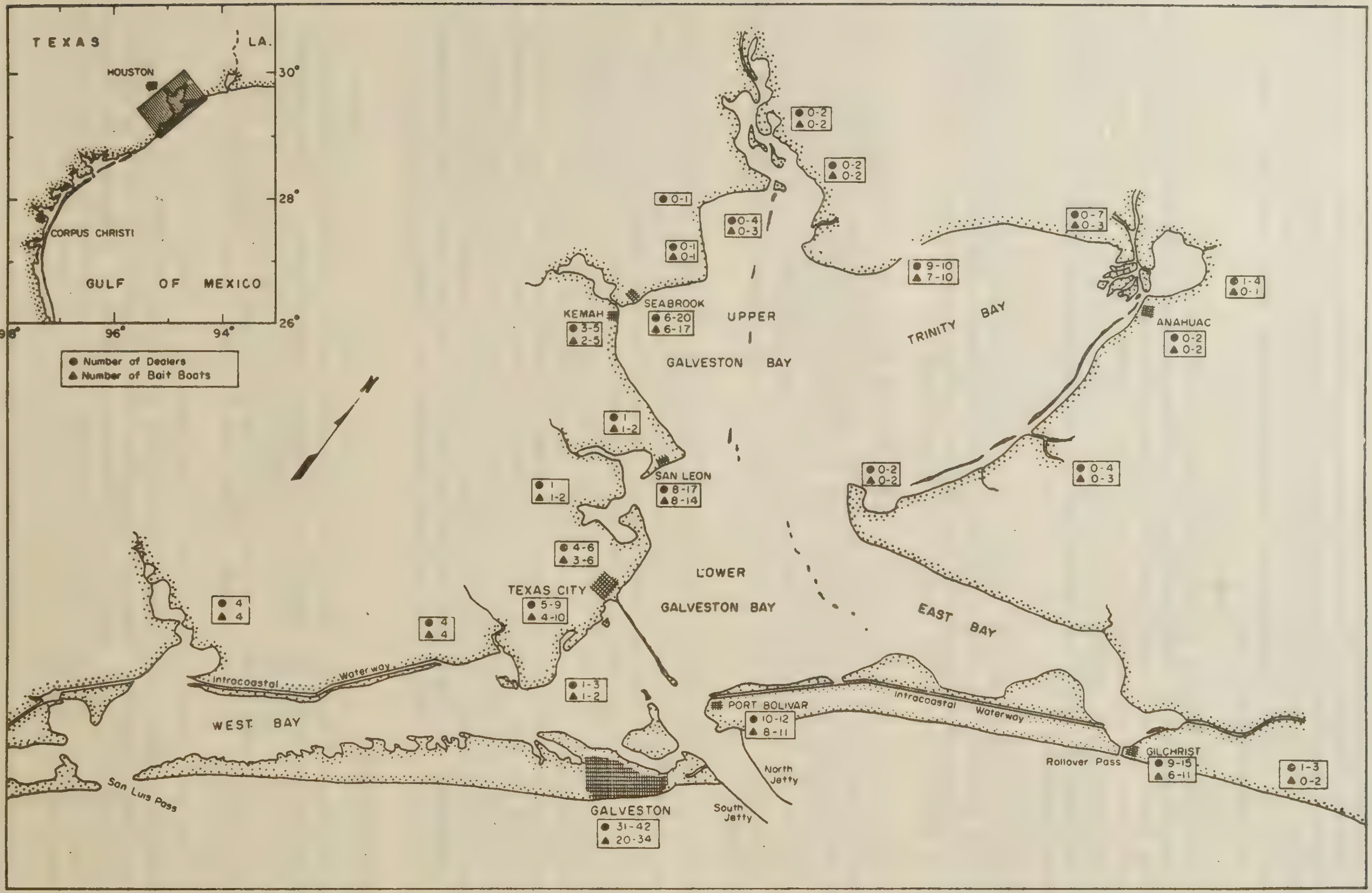
TEXAS
LA.
HOUSTON
CORPUS CHRISTI
GULF OF MEXICO
30°
28°
26°
98°
96°
94°
● Number of Dealers
▲ Number of Bait Boats
N
● 0-2 ▲ 0-2
● 0-2 ▲ 0-2
● 0-1
● 0-4 ▲ 0-3
● 0-1 ▲ 0-1
● 0-7 ▲ 0-3
● 9-10 ▲ 7-10
● 1-4 ▲ 0-1
SEABROOK
● 6-20 ▲ 6-17
KEMAH
● 3-5 ▲ 2-5
UPPER
GALVESTON BAY
TRINITY BAY
ANAHUAC
● 0-2 ▲ 0-2
● 1 ▲ 1-2
SAN LEON
● 8-17 ▲ 8-14
● 1 ▲ 1-2
● 0-2 ▲ 0-2
● 0-4 ▲ 0-3
● 4-6 ▲ 3-6
TEXAS CITY
● 5-9 ▲ 4-10
LOWER
GALVESTON BAY
EAST BAY
● 4 ▲ 4
● 4 ▲ 4
Intracoastal Waterway
WEST BAY
● 1-3 ▲ 1-2
PORT BOLIVAR
● 10-12 ▲ 8-11
Intracoastal Waterway
GILCHRIST
● 9-15 ▲ 6-11
Rollover Pass
● 1-3 ▲ 0-2
North Jetty
South Jetty
San Luis Pass
GALVESTON
● 31-42 ▲ 20-34

Fig. 8 Locations of bait dealers and bait boats in the Galveston Bay area, 1959–64.

species is no longer abundant in the bay after 31 July. Estimates of the average catch of brown shrimp per hour of fishing each week from 25 April to 31 July are shown in Fig. 9 for each year of our study. The original data were gathered by weekly periods, but minor adjustments were necessary to make the dates correspond among years in this figure. By summing weekly estimates of catch per effort for a season and dividing by the number of weeks (14), we obtain a single number proportional to the size of the brown shrimp stock in a given year. These figures must then be predicted from early season catch and effort data. The success of this approach depends on the similarity among years of the shape of the distribution of catch per effort at the same calendar periods. The formation of accumulative frequency distributions showed that the average catch per effort for the 14-week period could best be estimated from the average catch per effort from 25 April to 12 June. A close similarity exists between the early and full season measures of abundance in 6 of the 7 years, but not in 1963 (Fig. 10). Reference to Fig. 9 makes it apparent that in 1963 the stock of brown shrimp developed and moved out of range of the bait fishery earlier than usual.

On the basis of the positive relation between the growth of young brown shrimp and water temperatures demonstrated by Zein-Eldin and Aldrich (1965), it is reasonable to expect that unusually warm water influenced the early development of shrimp in 1963. Although water temperature data are not available, average air temperatures were above normal during March, April, and May 1963 (Table V). In fact, the average air temperature for April was the highest recorded in 1930-66.

TABLE V

Average monthly air temperatures (° C.) at the Galveston
Post Office Building for March, April, and May 1960-66
(Original data reported in ° F.)

Month	1960	1961	1962	1963	1964	1965	1966	91-year average
March	13.8	18.2	15.7	17.8	15.5	13.9	15.9	16.7
April	20.4	19.1	20.2	22.5	20.8	21.7	20.5	20.6
May	23.1	23.9	24.7	25.1	24.9	24.6	24.0	24.3
Average	19.1	20.4	20.2	21.8	20.4	20.1	20.1	20.5

Source: Local Climatological Data, Galveston, Texas. Weather Bureau, U.S. Department of Commerce.

3.3 Adult shrimp

Landing and effort statistics, recorded monthly in Gulf Coast Shrimp Data, provide the information required to measure the abundance of adult shrimp. Indices for adult brown shrimp were calculated as the average catch per hour in July, August, and September in offshore waters, as reflected by interviews. Possible biases in these data, caused by variations in the size of fishing vessels and from inclusion of fishing effort directed toward other species, were avoided by selecting the information used. To reduce the quantity of data from landings made by small, inshore vessels, only catches from depths greater than 20 m were incorporated into indices. Also, data were not used if species other than brown shrimp made up more than an incidental portion of landings.

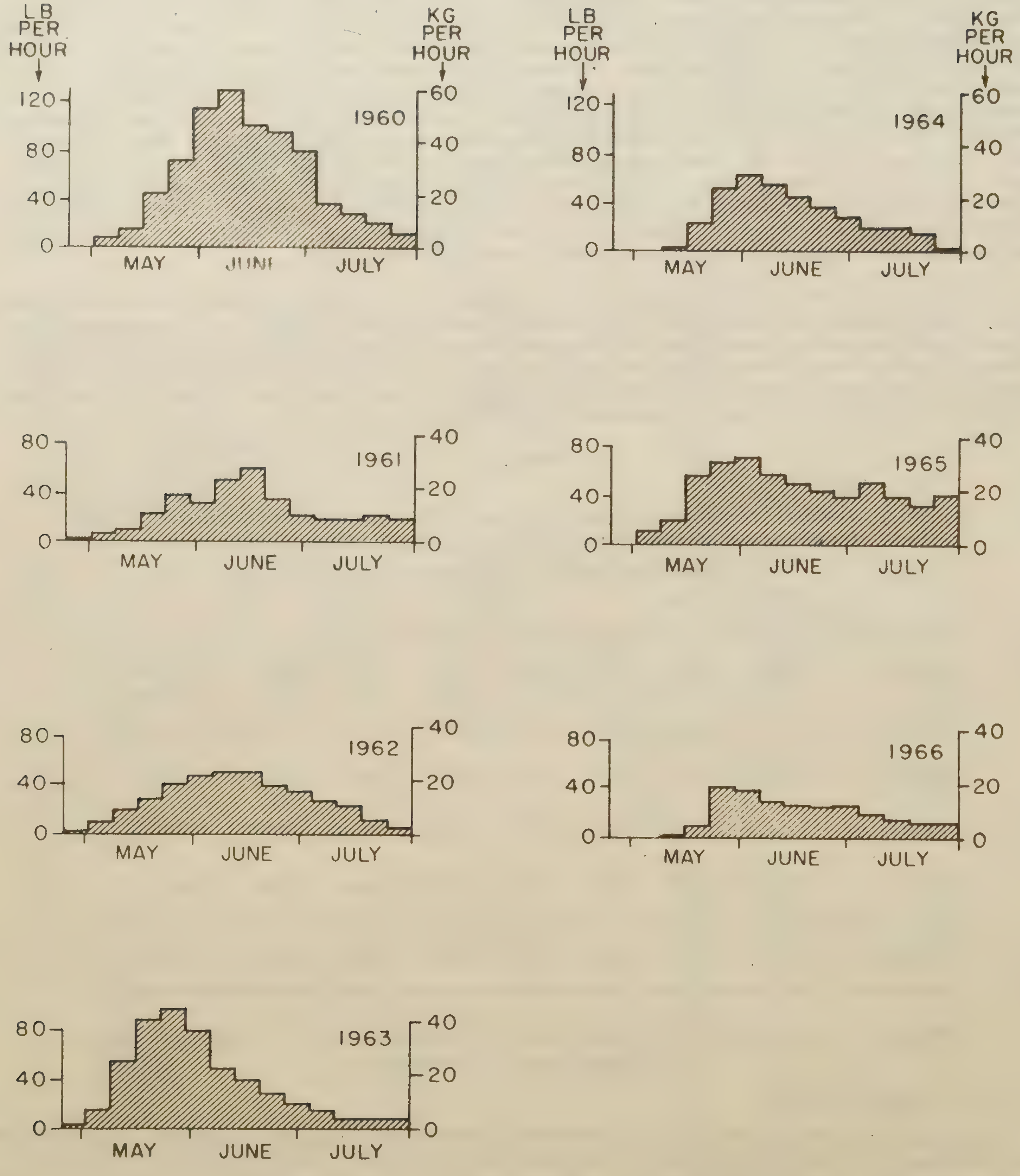

Fig. 9 Catch of brown shrimp per unit of fishing effort by the bait shrimp fishery in Galveston Bay, by weeks, from 25 April through 31 July, 1960-66.

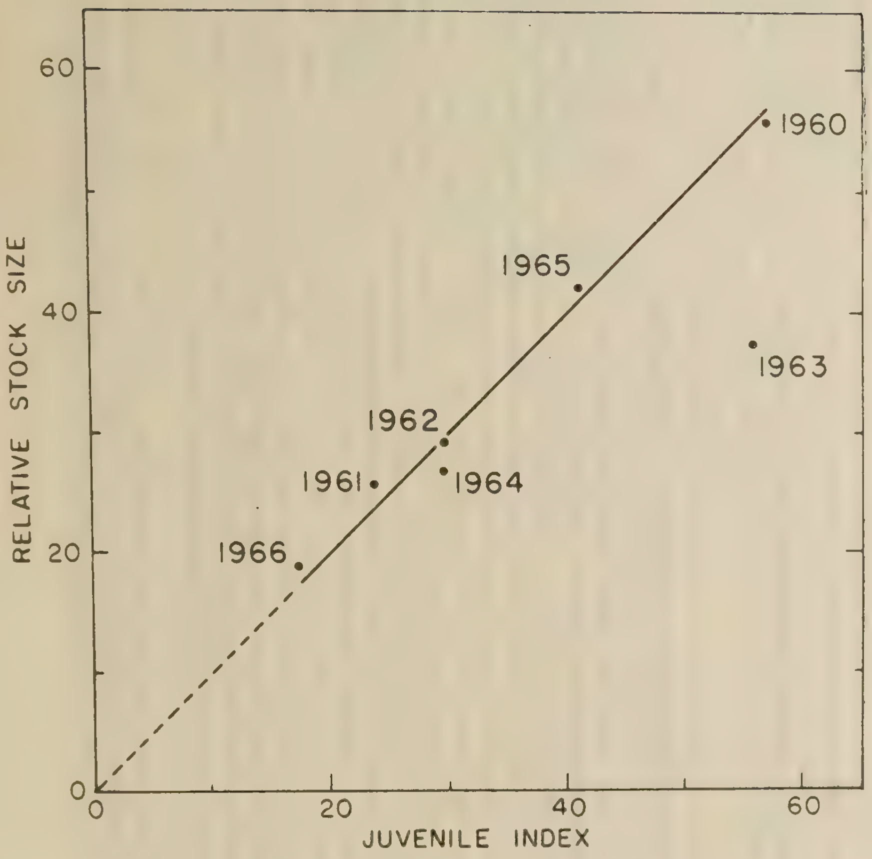

Fig. 10 The relation of the relative size of brown shrimp stocks from Galveston Bay (lb/h from 25 April to 31 July) and the index of juvenile brown shrimp abundance (lb/h from 25 April to 12 June). The equation $Y = bx$ was used to fit the line to observations (other than that for 1963) because the intercept of the line derived from $Y = a + bx$ did not differ significantly from zero.

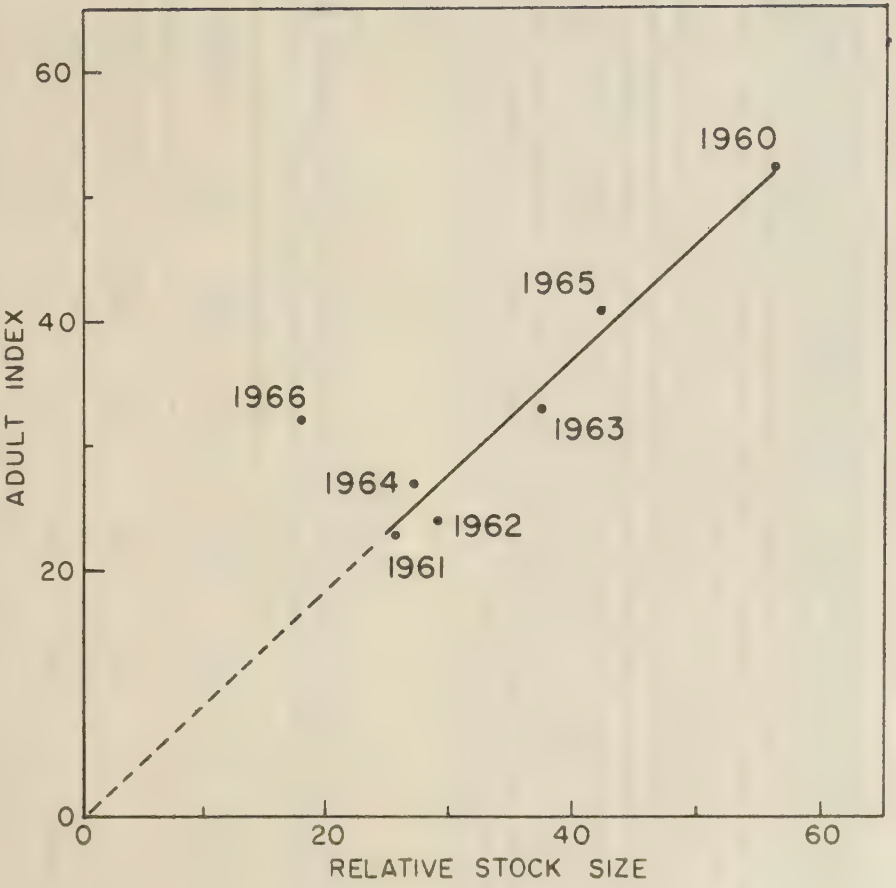

Fig. 11 The relation of the index to abundance of adult brown shrimp from subarea 18 (lb/h landed by the commercial fishery, July-September) and the relative size of stocks from Galveston Bay (lb/h landed by the bait shrimp fishery, 25 April to 31 July) for the years 1960-66. The equation $Y = bx$ was used to fit the line to observations (other than that for 1966) because the intercept of the line derived from $Y = a + bx$ did not differ significantly from zero.

3.3.1 Indices for adult shrimp from Galveston Bay Landing and effort data from subarea 18 (Fig. 2) were used to derive indices for brown shrimp that presumably had moved offshore from the Galveston Bay system. Numerical values for these indices are listed in Table VI along with indices of abundance of juvenile shrimp and estimates of the relative size of stocks in the bay each year from 1960 to 1966. To repeat the definitions of indices derived for bay populations: relative stock size is the average of weekly estimates of the weight of brown shrimp caught per hour by the bait shrimp fishery in Galveston Bay from 25 April through 31 July, and the juvenile index is formed by the same means from bait fishery data collected from 25 April through 12 June. Since these two measures differ little from each other for 6 of the 7 years tested (Fig. 10), it may be possible to predict relative stock size in the bay by 12 June in most years. A similar correlation exists between relative stock size and the index for adult brown shrimp in offshore waters of subarea 18 (Fig. 11). In this graph, the point for 1966 does not fall on the trend line, but those for other years are reasonably close to it.

TABLE VI

Abundance indices for juvenile and adult brown shrimp and the relative size of stocks originating from Galveston Bay in 1960-66

Measure of abundance	1960	1961	1962	1963	1964	1965	1966
Juvenile index	57	24	30	56[1]	29	41	18[2]
Relative stock size	56	26	29	37	27	42	19[2]
Adult index	52	23	24	33	27	41	32[2]

[1] The high index for juvenile brown shrimp in 1963 resulted from the unusually early emigration of shrimp from Galveston Bay

[2] The lack of agreement between measures in 1966 cannot be explained with certainty. Possible causes are discussed in the text

We can only speculate why the data for 1966 did not follow the trend established for other years. Either the adult index overestimated the crop of brown shrimp in offshore waters or the measure of stock size for juvenile shrimp in Galveston Bay underestimated their abundance. The index for adult brown shrimp may have been influenced by entry into the fishery of several new vessels that fish two, 16-to 21-m nets rather than the usual pair of 14-m nets. On the other hand, unusual environmental conditions within Galveston Bay may have affected catches in the bait shrimp fishery. Abnormally large quantities of fresh water from spring floods that decreased the salinity of bay waters in May 1966 (Table VII) may have caused young shrimp to move seaward before they normally would do so. Measurements of total lengths of juvenile brown shrimp caught at the entrance to Galveston Bay averaged 49 mm on 11 May (Trent, personal communication) and 58 mm on 18 May (Trent, 1967). These shrimp were considerably smaller than those collected by Trent on later dates. Conceivably, part of the stock normally fished by the bait fishery moved beyond its reach and depressed abundance indices based on catches in the bay.

A final correlation, and the one of principal interest from the viewpoint of predictions, can be made between the indices for juvenile and adult brown shrimp. We have not portrayed these data in a graph because the relation between them is evident from the values listed in Table VI. The two measures are similar in 5 of the 7 years, but not in 1963 or 1966. With the exception of these 2 years, it would have been possible to predict the average fishing success (catch per hour) for offshore brown shrimp in July, August and September as early as 12 June.

TABLE VII

Measurements of the volume (million m^3) of fresh water carried into Galveston Bay by the Trinity River during the spring, 1963-66

Month	1963	1964	1965	1966
March	137	286	604	192
April	206	288	483	729
May	583	216	1,441	3,943
June	195	147	1,052	858

Source: Water Resources Division, U.S. Geological Survey, Austin, Texas

3.3.2 Indices for other areas of the Gulf We have calculated index numbers for brown shrimp in the offshore waters of subareas 11 and 13 through 21 (see Fig. 2 for locations) for those years for which interview information is available (Table VIII). These numbers, which represent the average weight of brown shrimp landed per hour of fishing from July through September, indicate that the relative density of this species was more similar within than between years over the range of the fishery from Alabama to the Mexican border. This region supplied 75 to 90 percent of the total U.S. landings of Gulf brown shrimp.

We are confident that, in general, these indices provide a correct picture of the abundance of brown shrimp, but several possible sources of error limit the value of comparisons among individual index numbers. The proportion of interviews obtained from vessel captains varies within and between subareas and seasons. Likewise, the depths in which fishing intensity is greatest, and consequently, the average size of shrimp caught, differs within and between regions and months. Because of these shortcomings in the basic data, statistical analyses would add little to our interpretations of the index numbers. We can, however, help to substantiate differences between years by reference to landings from sections of the Gulf coast. A comparison of average index numbers and total annual harvests from Louisiana and Texas waters for 1958-65 shows that when total fishing effort remains at about the same level, as it did in these years, the indices provide good indications of total harvest (Fig. 12).

It is tempting to speak of predicting the relative abundance of brown shrimp along all of the Texas coast or over the entire northwestern portion of the Gulf of Mexico from estimates obtained from the bait fishery of Galveston Bay. Despite the strong correlations existing among these measures, we believe that predictions for such a broad area should be based on data from more than one sampling location.

Certain generalizations are justified on the basis of evidence presented concerning so-called good and poor years for brown shrimp:

TABLE VIII

Indices to the abundance of adult brown shrimp (July-September) in subareas 11 and 13 through 21 for the years 1958-1965. Indices for each subarea are ranked between years to facilitate comparisons

Subarea	1958	1959	1960	1961	1962	1963	1964	1965
11								
Index	25	37	36	19	17	31	32	35
Rank	6	1	2	7	8	5	4	3
13								
Index	27	32	38	19	22	31	20	35
Rank	5	3	1	8	6	4	7	2
14								
Index	26	42	37	24	21	38	22	48
Rank	5	2	4	6	8	3	7	1
15								
Index	28	33	37	22	18	33	25	29
Rank	5	2.5	1	7	8	2.5	6	4
16								
Index	36	41	44	21	17	41	26	38
Rank	5	2.5	1	7	8	2.5	6	4
17								
Index	32	50	65	25	21	34	27	38
Rank	5	2	1	7	8	4	6	3
18								
Index	33	49	52	23	24	33	27	41
Rank	4.5	2	1	8	7	4.5	6	3
19								
Index	33	44	45	22	21	33	25	36
Rank	4.5	2	1	7	8	4.5	6	3
20								
Index	27	49	45	25	26	35	28	39
Rank	6	1	2	8	7	4	5	3
21								
Index	27	46	41	28	25	33	24	34
Rank	6	1	2	5	7	4	8	3
Average Index	29	42	44	23	21	34	26	37
Rank	5	2	1	7	8	4	6	3

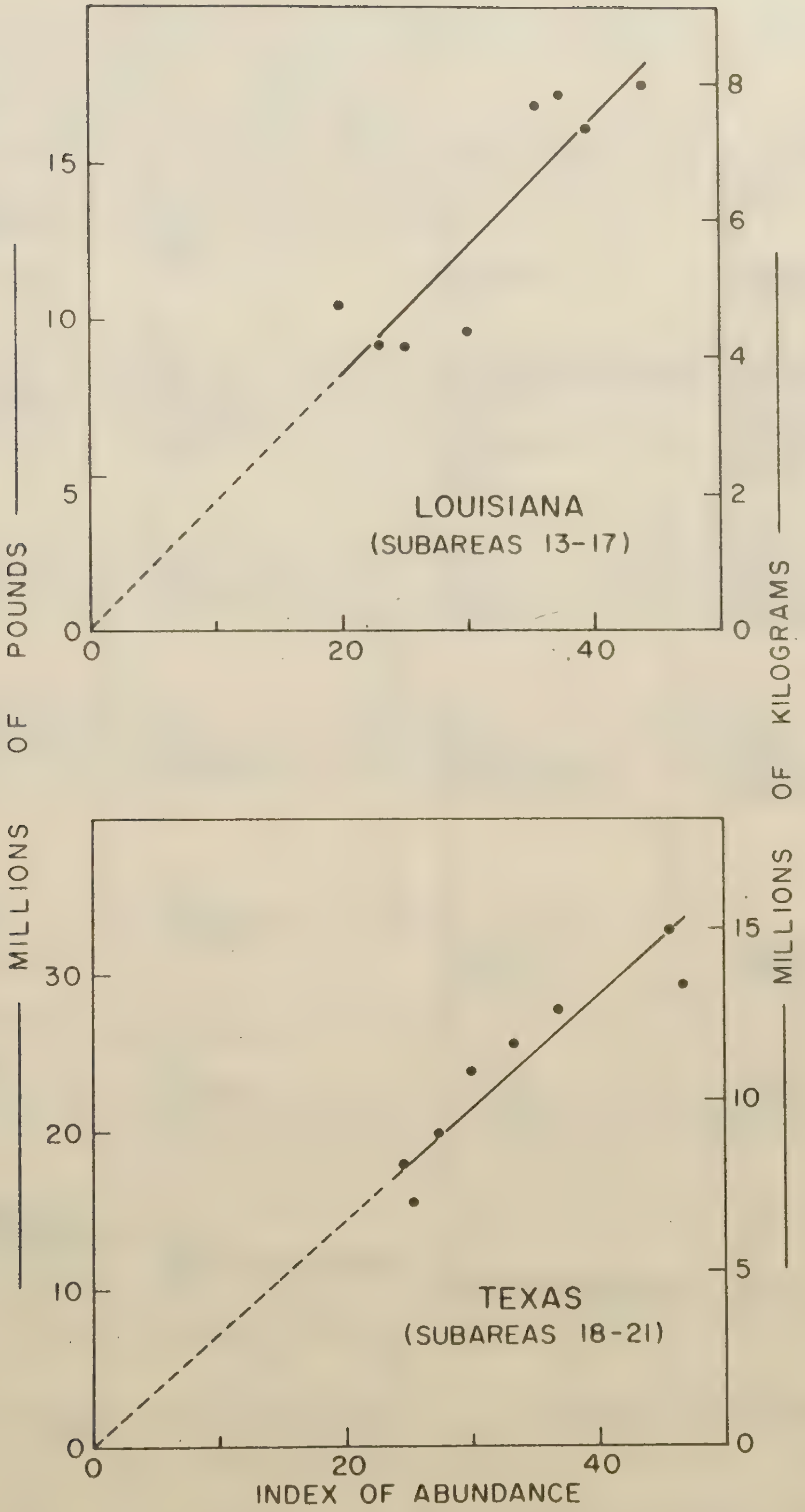

Fig. 12 The relation of annual landings and average indices of abundance of adult brown shrimp along the Louisiana and Texas coasts, 1958-65.

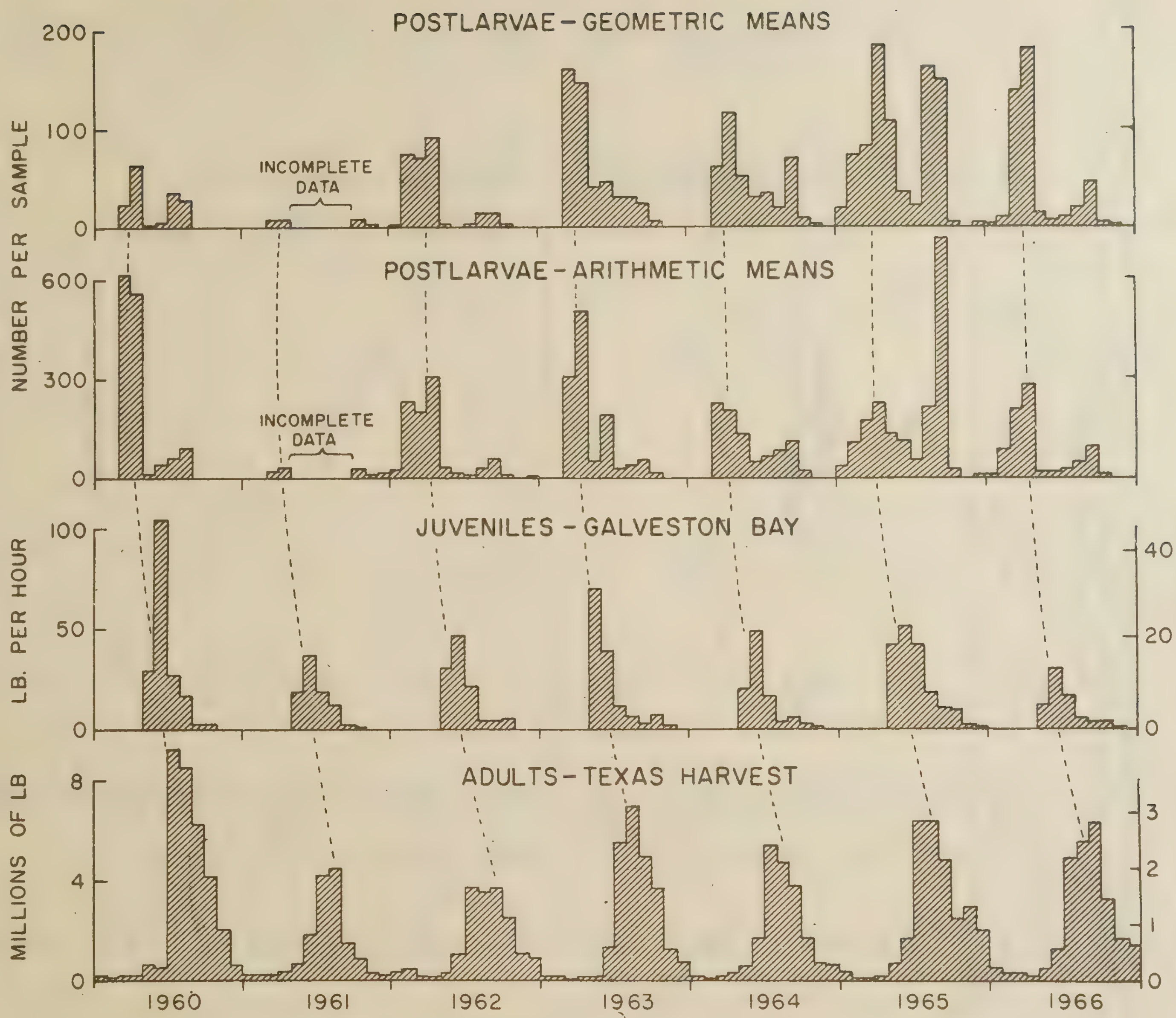

Fig. 13 Abundance of brown shrimp at the postlarval, juvenile and adult stages by months, 1960-66.

(i) Predictions of size of brown shrimp stocks in the Gulf of Mexico may require information (concerning the relative abundance of postlarvae or juveniles) from a relatively small number of judiciously selected sampling sites.

(ii) Of the many factors that influence the size of brown shrimp populations, only those that affect broad areas of the Gulf have a major effect on abundance. This implies that current fishing practices, such as differences in the time and intensity of fishing, or variations in laws regulating catches have little influence on population size, although they obviously affect harvests.

4 CONCLUDING REMARKS

We have emphasized problems in sampling postlarvae and the interpretation of postlarval counts. These topics assume major importance when one speaks of the statistical significance of an index number or the reliability of a prediction. At the present early stage of such studies, it is equally important to recognize that collections of postlarvae can be used to advantage, even though forecasts must be of a very general nature.

The relation between our catches of postlarvae and the later abundance of juvenile and adult brown shrimp is shown in Fig. 13 for 1960-66. Again, postlarval abundance is portrayed in terms of both the arithmetic and geometric averages of monthly counts. Adult abundance is shown as monthly landings of brown shrimp from the Texas coast.

Finally, we wish to make a distinction between forecasts of adult abundance based on postlarval and juvenile indices. Despite serious problems in the sampling of postlarvae, we believe that predictions based on postlarval indices have greater potential value to the shrimp industry than those made from catches of juvenile shrimp because the information is available 4 to 6 weeks sooner.

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THE BIOLOGY AND DISTRIBUTION OF THE NORTHERN SHRIMP (Pandalus borealis Kr.) IN THE BERING SEA AND THE GULF OF ALASKA

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Abstract

Explorations in the North Pacific in recent years have revealed considerable stocks of Pandalus borealis Krøyer in the Bering Sea and the Gulf of Alaska. Studies on size composition show that the shrimp catches are mostly made up of specimens aged between 1½ and 5½ years; a few survive to 6½ years. Size at first maturity (as males), at sex-change and at second maturity (as females) was also studied. The strength of different year-classes can be largely explained from the character of the first winter after hatching and the abundance of the parent year-classes.

Three ecological zones are recognizable within the area considered. Large concentrations of shrimps tend to form in the zone of interaction of two water masses rather than in waters of a particular temperature. Local circulations due to islands and bays help to prevent the dispersal of larvae to unfavourable areas.

E/43

BIOLOGIE ET REPARTITION DE LA CREVETTE NORDIQUE DANS LA MER DE BERING ET LE GOLFE DE L'ALASKA

Résumé

Des campagnes de prospection menées dans le Pacifique Nord ces dernières années ont révélé la présence de stocks considérables de Pandalus borealis Krøyer dans la mer de Béring et le golfe de l'Alaska. L'étude de la composition par taille a indiqué que les captures comprennent principalement des crevettes d'un âge situé entre 1,5 et 5,5 ans; quelques unes atteignent 6,5 ans. Les recherches ont porté également sur la taille à la première maturité (en tant que mâles), à l'inversion du sexe et à la seconde maturité (en tant que femelles). L'importance des différentes classes d'âge s'explique en grande partie par les caractéristiques du premier hiver qui suit l'incubation et par l'abondance de la classe d'âge des géniteurs.

On distingue trois zones écologiques dans la région étudiée. Le fortes concentrations de crevettes tendent à se constituer plutôt dans la zone d'interaction de deux masses d'eau que dans des eaux d'une température déterminée. La présence d'îles et de baies détermine des circulations locales qui contribuent à empêcher la dispersion des larves vers des régions défavorables.

LA BIOLOGIA Y DISTRIBUCION DEL CAMARON SEPTENTRIONAL EN EL MAR DE BEHRING Y EN EL GOLFO DE ALASKA

Extracto

Las exploraciones efectuadas en el Pacífico septentrional durante estos últimos años han revelado la existencia de considerables poblaciones de Pandalus borealis Krøyer en el Mar de Behring y en el Golfo de Alaska. Los estudios sobre la composición por tallas indican que las capturas de camarones están formadas en su mayor parte por ejemplares de edades comprendidas entre 1,5 y 5,5 años; algunos sobreviven hasta los 6,5 años. También se estudió la talla durante la primera madurez (en los machos) durante el cambio de sexo y en la segunda madurez (en las hembras). El volumen de las diferentes clases de edad se puede explicar, en gran parte, por las características del primer invierno después de la eclosión y por la abundancia de la clase de edad de los padres.

Dentro del área considerada se pueden reconocer tres zonas ecológicas. En la zona de interacción de dos mases de agua tienden a formarse grandes concentraciones de camarones en vez de formarse en aguas de una determinada temperatura. Los movimientos de agua de tipo local que tienen lugar, debido a la existencia de islas y bahías, contribuyen a evitar la dispersión de las larvas hacia zonas desfavorables.

1 INTRODUCTION

The many exploratory cruises conducted in the last few years in the North Pacific have revealed appreciable stocks of shrimp in the Bering Sea and the Gulf of Alaska. Now the stocks are exploited by the fishermen of Japan, the U.S.A. and U.S.S.R. The present paper is a brief summary of the Soviet investigations on the biology and distribution of the Pandalus borealis Krøyer, a species of a great commercial interest in the Bering Sea and the Gulf of Alaska. The carapace length (cl), from the posterior limit of the eye socket to the extreme posterior lateral edge of the carapace, is the main size measurement used.

2 ENVIRONMENTAL INFLUENCES ON YEAR CLASSES

2.1 The Bering Sea

Data for the Pribilof area of the Bering Sea are available for August, November and December 1962; January, February, August 1963; May 1964; and May 1965. The shrimp size composition in trawl catches for those months is given in Fig. 1. The growth of the shrimps in the Pribilof area is represented in Fig. 2. From the diagrams of the shrimp size and sex composition it can be seen that in the Pribilof area shrimps at the age of 1½yr (cl = 12 to 13 mm) are still not sexually mature. Some shrimps at the age of 2½ yr (cl = 18 to 19 mm) still remain immature, while others become males and participate for the first time in the autumn breeding. Shrimps 3½ yr old (cl = 22 mm) are nearly all males, and only a small minority are females. Most specimens of 4½ yr (cl = 24 to 25 mm) again act as males, and only at the age of 5 yr do the bulk of shrimps change their sex. At the age of 5½ yr (cl = 27 mm), in autumn, they begin to spawn. A very small number of shrimps can survive up to 6½ yr, and many of these are sterile females. Thus, in the Pribilof area the majority of females have only one brood.

From the peaks in the diagrams of the size composition one can estimate the relative strength of shrimp year-classes. If all the age groups of shrimps (that is shrimps at the age of 1½, 2½, 3½, 4½ and 5½ years) had been equally represented in the catches, the shrimps with cl = 12 to 13, 18 to 19, 21 to 22, 24 to 25 and 27 mm should have formed the peaks in the August diagrams of size composition. But, the peaks are different sizes and can be even practically absent (Fig. 1). (Shrimps in their first year are poorly represented in the samples and are omitted from the figure). For instance, in August 1962 shrimps with cl = 18 to 19 mm formed no noticeable peak in the catches, but shrimps of the same size showed a well marked peak in August 1963. Shrimps with cl = 24 mm also did not form an obvious peak in August 1962, but they did in August 1963. As seen from 1962 and 1963 diagrams, the 1960 year-class was extremely poor, and was practically absent, the 1959 year-class was rich, the 1958 year-class was average, the 1957 year-class was rich, and the 1961 year-class was, apparently, rich.

Comparing the strength of the 1957-61 year-classes with ice conditions in the Bering Sea (Fig. 3) one can notice that year-classes which went through a mild or moderate winter in the first year of life can usually be considered as rich, and the shrimps representing the poor 1960 year-class were hatched before a severe winter. Thus, fluctuations in the abundance of the Pribilof shrimps can be fairly well explained by the assumption that the strength of year-class depends on the character of the first winter after hatching.

This assumption and records of ice conditions in the Bering Sea in the previous years (Kryndin, 1964) make it possible to estimate the strength of the parent year-classes which gave rise to the 1957-61 broods (Fig. 3). We assume that all the females in the hatching period were 6 yr old. Assuming that the abundance of the year-classes depends to some extent on the strength of their parent year-classes, we can explain further the fluctuations in the abundance of the 1957-61 year-classes.

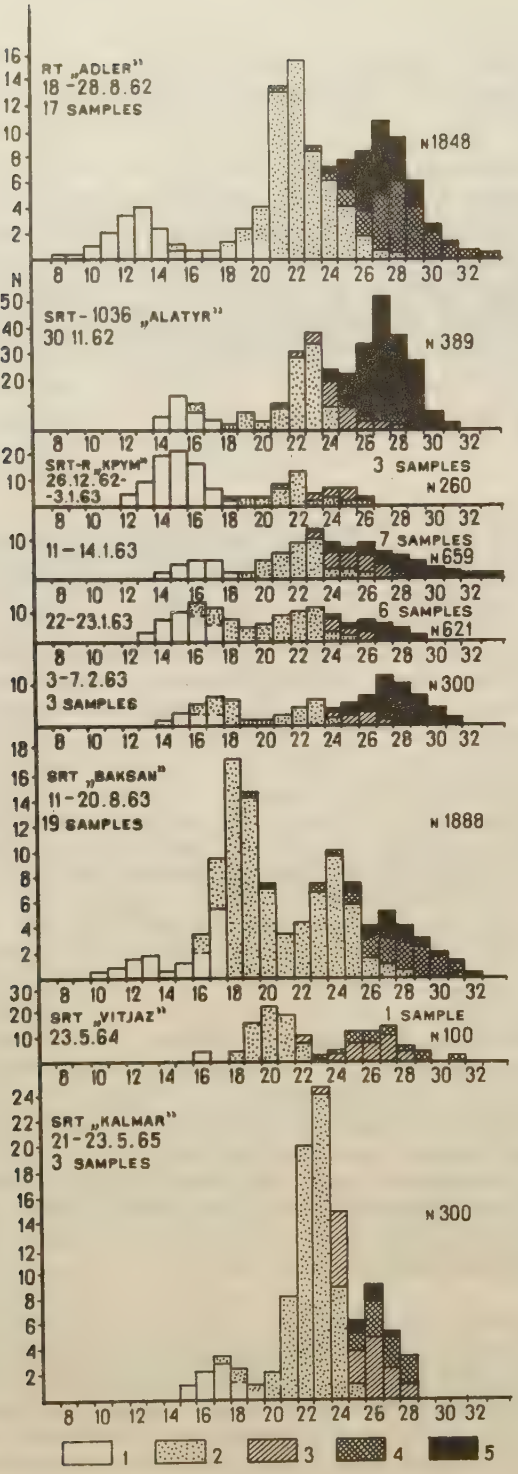

Fig. 1 Size and sex composition in P. borealis catches in the Bering Sea (axis X, carapace length):
1 Juvenile, 2 Males, 3, Transitional
4 Females, 5 Ovigerous females

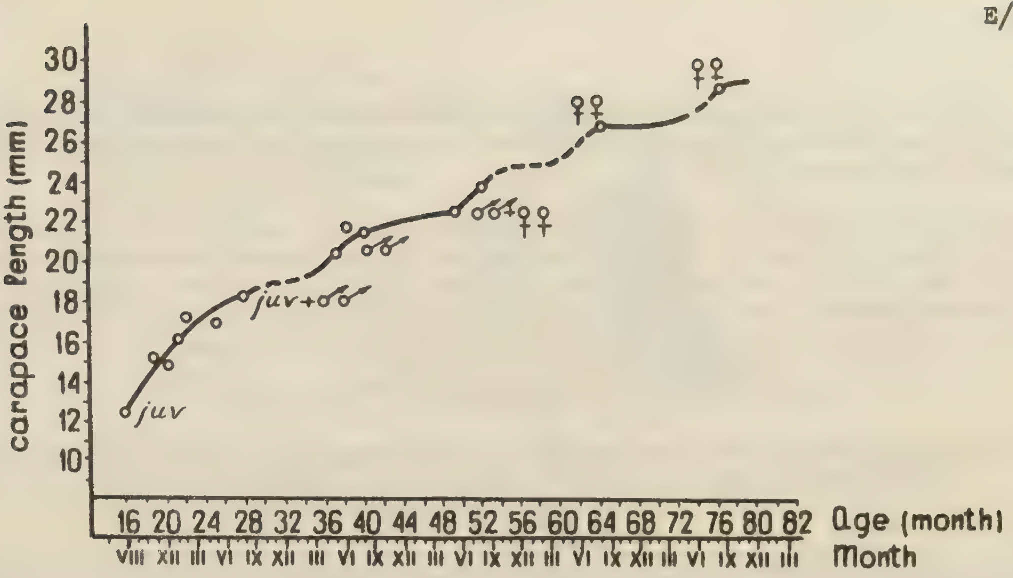

Fig. 2 Growth of P. borealis in the Bering Sea.

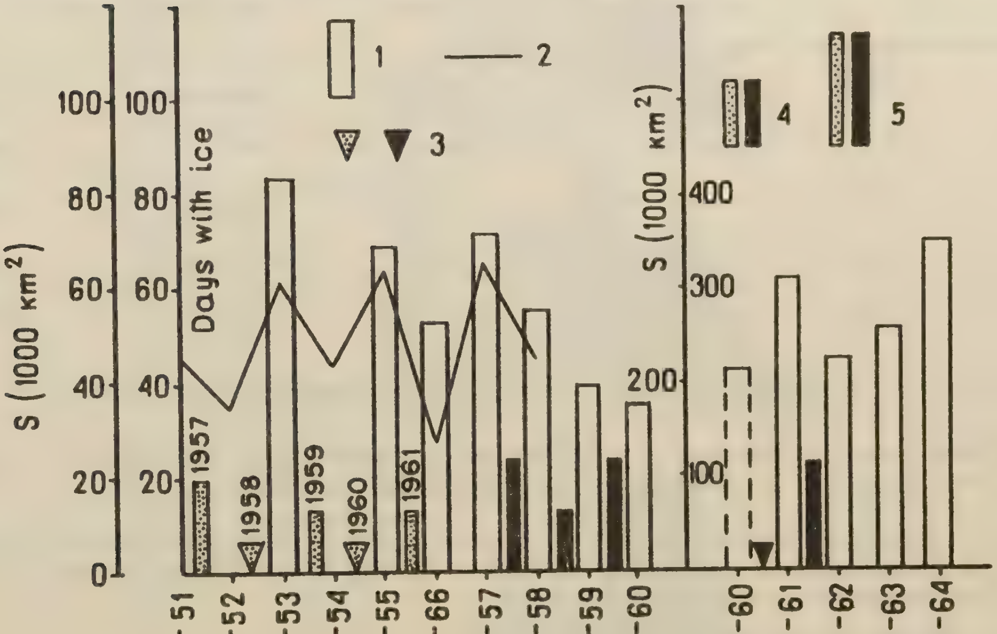

Fig. 3 Relation between ice conditions in winter and the strength of the P. borealis year-classes in the Bering Sea:

1 Sea area covered by ice in thousands of km^2 (left, western Bering Sea (after Kryndin, 1964); right, whole of Bering Sea)

2 Days with ice (after Kryndin, 1964)

3 Poor year-class

4 Average year-class

5 Rich year-class (dotted, parent year-classes; black, the considered year-classes)

The fact that the 1958 generation was of only moderate strength, in spite of the mild winter which followed its hatching, can be explained by the supposed low abundance of the parent year-class of 1952.

Interrelations between the strength of year-classes, severity of the winter in the first year of shrimp life, the supposed strength of the parent year-classes are given in Table I. So, it is possible that the strength of different year-classes of the Pribilof shrimps depends on the winter character in the first year of the shrimp life and to a lesser degree on the abundance of the parent year-classes.

TABLE I

The relation between the strength of year-classes, the winter climate during the first year of shrimp life and the supposed strength of parent year-classes

Year-class	Birth of parent year-classes	Winter character in the first yr of life of parent year-classes	Supposed strength of parent year-class	Winter character in the first yr of life of the given year-class	Strength of the year-class
1957	1951	mild	rich	moderate	rich
1958	1952	severe	poor	mild	average
1959	1953	moderate	average	mild	rich
1960	1954	severe	poor	severe	very poor
1961	1955	moderate	average or rich	mild	rich

Taking into account the short series of our observations, we consider this as a preliminary conclusion to be checked by further investigations.

Since the Japanese fishermen carry out an intensive fishery for the Pribilof shrimps, it is possible that data on the catches of the various year-classes will help to check our conclusions in the near future.

2.2 The Western Part of the Gulf of Alaska

Data for the west part of the Gulf of Alaska (Kodiak-Sanak Islands) are available for December 1962, August 1963, March and May 1965 (Fig. 4). The growth of shrimps in the west part of the Gulf of Alaska is represented in Fig. 5. Because of the lack of continuous series of observations it is difficult to assess growth, sex maturation and fluctuations in the abundance of different year-classes.

It seems that in the western Gulf of Alaska shrimps at the age of 1½ yr (cl = 13 mm) remain immature and first participate in breeding as males at 2½ yr (cl = 19 mm).

Most specimens of 3½ yr (cl = 22 mm) again act as males, but some of them change sex and spawn. Change of sex takes place, in the main, at the age of 4 yr, and the majority of shrimps spawn for the first time at the age of 4½ yr (cl = 25 mm). Unlike

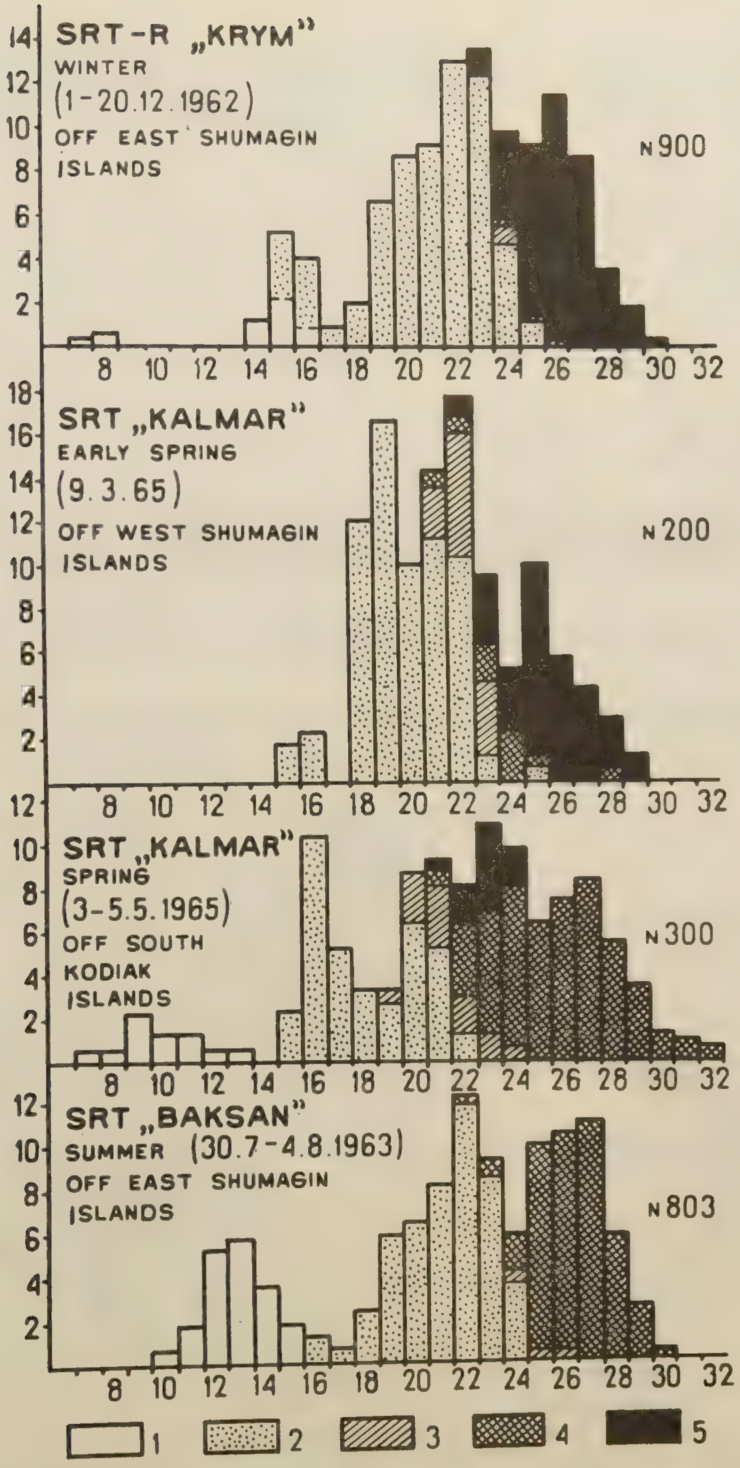

Fig. 4 The size and sex composition in P. borealis catches in the western part of the Gulf of Alaska. (Signs used are the same as for Fig. 1)

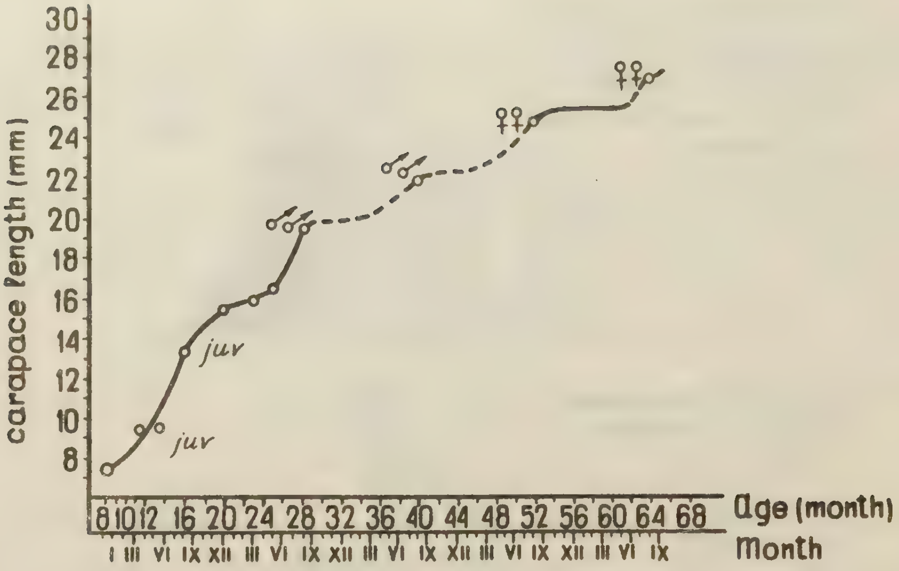

Fig. 5 The growth of the *P. borealis* in the western Gulf of Alaska.

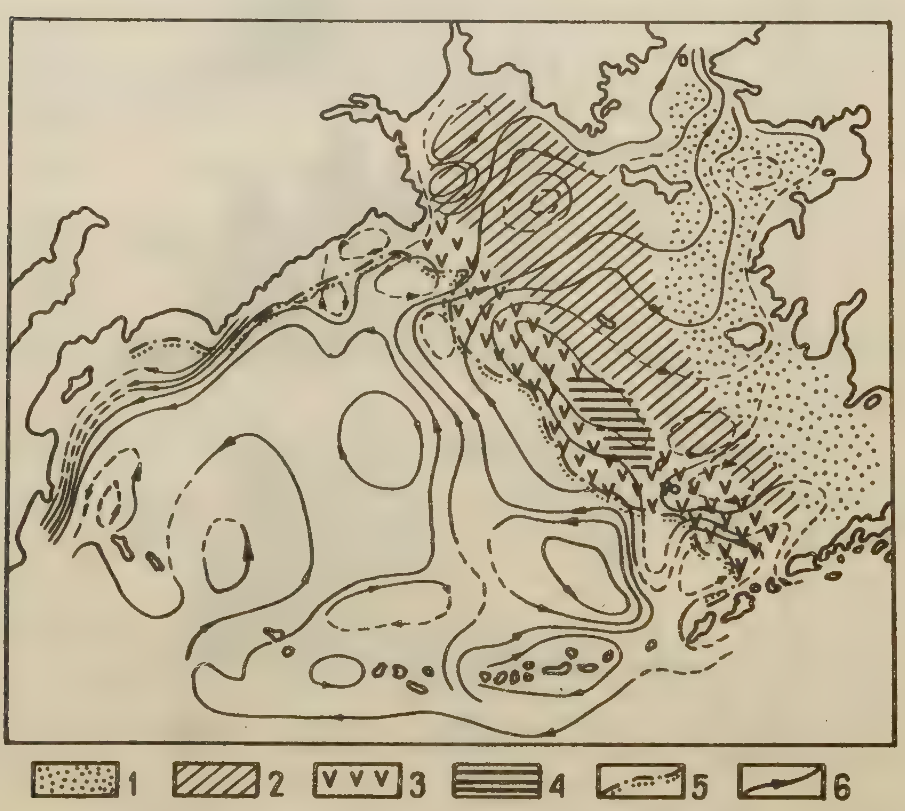

Fig. 6 Map of surface currents in the Bering Sea in June (after Arsenyev and Shcherbinin, 1963) with the location of the three ecological zones and the area of the Pribilof shrimp concentration :

1 zone with sharp seasonal fluctuations in temperature
2 zone with constant low off-bottom temperature
3 zone warmed up by deep waters from the continental slope
4 area of the Pribilof shrimp population
5 200 m isobath
6 lines of equal dynamic height (10 db to 1,000 db) with direction of currents

the Pribilof shrimp population, in the Gulf of Alaska numerous females breed twice, as 4½ and 5½ yr old specimens (cl = 27 to 28 mm). Very few specimens live till 6½ yr (cl = 30 mm). Thus, in the western Gulf of Alaska sex development takes place one year earlier than in the Bering Sea.

As seen from the diagrams (Fig. 4), in the Gulf of Alaska (unlike the Bering Sea) sharp fluctuations in the strength of different year-classes are not observed. This fact can be, apparently, explained by the milder conditions. Thus, taking into consideration that a number of Alaskan females spawn twice, the lack of great fluctuations in the year-class strength and the more rapid sexual development of shrimps as compared with the Bering Sea, one can conclude that the western Gulf shrimp concentrations are more stable than those in the Bering Sea.

The western part of the Gulf of Alaska contrasts with the eastern part (Butler, 1964; Anon., 1965), and with European waters (Rasmussen, 1953; Horsted and Smidt, 1956; Allen, 1959), in that growth and sexual development of shrimps do not slow down towards the north. For instance, sex change of shrimps in the Shumagin Islands takes place at 4 yr, the same age as in the northern Gulf (5° further north) Anon., 1965. There is even a slight tendency for growth and sexual development to be faster in the northern than in the south-western Gulf. The size and sex composition of shrimp populations in the western Gulf of Alaska are relatively uniform over a very wide range of both latitude and longitude, and correlations with latitude may even be reversed from those found on the Norwegian coast. Comparable conditions are not found elsewhere within the range of P. borealis, but they are explained by the warm current which flows through the western Gulf from northeast to southwest. This results in milder hydrological conditions in the northern part of the area than in the southwest.

3 SHRIMP DISTRIBUTION

3.1 The Bering Sea

Three ecological zones, which are mainly distinguished by temperature, can be recognized on the Bering Sea shelf. The zones stretch like belts parallel to the continental slope. The existence of the zones is determined by the contact of different water masses with the bottom. These zones are:

(i) zone with sharp seasonal fluctuations of temperature (warming in summer, cool in winter);

(ii) zone with constant low off-bottom temperature (bottom layer of residual winter cooling);

(iii) zone warmed up by deep waters of the continental slope.

Every water mass, and, hence, every zone, is characterized by its own shrimp species. Zone (i) occupies the sandy coastal areas of not more than 50 m in depth; Crangon dalli is the most common species of shrimp. Zone (ii) extends from 50 m to 70 to 100 m; the bottom is mainly muddy, and the cold-water forms, Eualus macilentus and Pandalus goniurus, are the most typical species. Thermal conditions favouring P. borealis are observed only in zone (iii) (deeper than 70 to 100 m), and it is the dominant species in this zone. Thus, in the Bering Sea winter cooling is a significant limiting factor in the distribution of P. borealis, which is largely restricted to the zone where cooling is minimal.

Despite the wide distribution of P. borealis in the zone warmed up by deep water, its commercial concentrations occur only off the Pribilof Islands. The formation of the Pribilof population is determined by the combined action of three factors: a favourable thermal regime, since the area is greatly warmed up by deep waters; the presence of a large muddy area; and the closed water circulation (Fig. 6). As a result of this last factor, shrimp larvae do not drift into unfavourable regions for development.

Although the P. borealis is widely distributed in zone (iii), its commercial concentrations are not observed in the warmest layers of the zone, where it might be expected. The shrimps tend to concentrate in the upper layers of the zone, close to the zone of constant low off-bottom temperature. Hence, the Bering Sea shrimp concentrations are found in the zone of interaction of two water masses.

The position of borders between the zones (ii) and (iii) is variable. Due to the winter cooling, zone (ii) enlarges and the zone (iii) decreases correspondingly. Consequently, in winter the Pribilof population migrates 30 to 40 miles southwestward, approaching the continental slope, moving from the summer depths (85 to 100 m) to a depth of 95 to 120 m. In severe winters, cold waters with the temperature below zero can even cover areas of shrimp concentrations. Since a very flat bottom is characteristic of the Pribilof area, shrimp distribution depends very little on the bottom relief, and the influence of hydrological conditions on their distribution becomes especially apparent.

The Pribilof population differs from others in a number of respects. It is the only concentration located at a long distance from the continent; it occupies a very large area; heavy concentrations of shrimps can be recorded there; shrimp distribution is almost independent of the bottom relief, and the shrimps carry out rather large seasonal migrations of 30 to 40 miles (56 to 74 km).

3.2 The Gulf of Alaska

In contrast to the Bering Sea, winter cooling is not an important limiting factor for the P. borealis distribution in the Gulf of Alaska. Complex relief and bottom deposits are of much greater importance than in the Bering Sea. Relief and deposits greatly disguise the dependence of shrimp distribution upon water masses, but this dependence is distinctly manifested in the comparatively well investigated Shumagin region.

Comparing shrimp distribution with the off-bottom isotherms, one can note that the maximum catches of shrimps are usually in the zone of sharp temperature gradients, where the mixing of different water masses apparently takes place. Besides, off the Shumagin Islands shrimps avoid the zone where a warm intermediate layer (apparently, a branch of warm Alaska current) is in contact with the bottom.

P. borealis appears to show a general tendency to form concentrations in the zone of interaction of water masses of different origin, and not in waters with some optimum temperature.

The U.S.A. and U.S.S.R. surveys in the Gulf of Alaska (Greenwood, 1959; Johnson, 1959; Ronholt, 1963; Rathjen and Yesaki, 1966; Ivanov, 1963, 1964) supplement each other well, because the American surveys were conducted mainly within the 12 mi (22 km) zone and the Soviet surveys have all been outside this zone. These surveys show that it is in the west part of the Gulf (off the Kodiak and, particularly, Shumagin Islands) that the largest stocks of shrimps occur, both in the inshore and offshore waters.

Apparently, the comparatively wide shelf of the western Gulf, with numerous muddy grooves and hollows, is more favourable for the formation of concentrations than the narrow rocky fjords of the southeastern part of the Gulf. Both islands and bays help to create the circulation system which prevents larvae from drifitng away into unfavourable areas. This makes the western part of the Gulf more favourable for P. borealis than the central part and it is the most commercially important area.

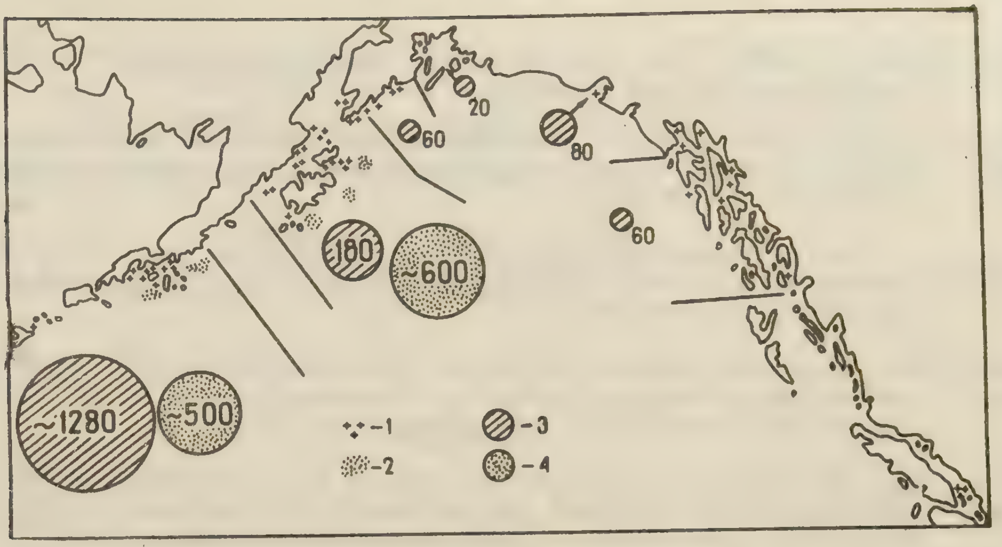

Fig. 7 Inshore and offshore shrimp fishing areas in the Gulf of Alaska and catches from these areas; data on inshore grounds from Ronholt (1963) and Butler (1964), data on offshore grounds original:

1 areas of inshore concentrations, 2 areas of offshore concentrations,
3 average catch kg/h of inshore areas, 4 average catch kg/h of offshore areas.

The northern shrimp commercial concentrations in the Atlantic and Pacific can be classified into three types in relation to their remoteness from the continent:

(i) fjord and bay concentrations in the close vicinity of the coast;

(ii) offshore concentrations within a short distance, not farther than 30 to 40 mi (56 to 74 km) of the coastline;

(iii) offshore concentrations at long distance from the coast.

The first type comprises concentrations in fjords of the Scandinavian countries and those in the coastal zone of the Gulf of Alaska. The second one involves the concentrations off the East and West Shumagin, South and North Kodiak in the Pacific and those off the Skagerrack. The third includes only the Pribilof concentrations in the Bering Sea.

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KURUMA SHRIMP (Penaeus japonicus) CULTIVATION IN JAPAN

by

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Abstract

The history of Karuma shrimp cultivation in Japan is traced from the first attempts to rear Penaeus japonicus in the laboratory in 1933 to the large-scale commercial rearing practised in 1967.

Successful rearing on a large scale was first achieved in indoor tanks, using cultures of the diatom Skeletonema costatum as food for the zoeal stages, Artemia nauplii for the mysis and post-larval stages and crushed clam meat for the juvenile stages. The scale of operations has been greatly increased and the cost of production lowered by using large outdoor tanks filled with natural seawater to which nutrient salts are added. The resulting bloom of phytoplankton makes the separate culture of diatoms unnecessary, and wild zooplankton and benthos develop to a considerable degree, so that only relatively small amounts of Artemia and clam meat need be added.

Current research is largely directed to finding suitable foods, other than potential human foods, for juvenile shrimp.

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LA CULTURE DE LA CREVETTE KURUMA (Penaeus japonicus) AU JAPON

Résumé

Historique de l'élevage de la crevette Kuruma au Japon, depuis les premières tentatives (1933) d'élevage en laboratoire de Penaeus japonicus jusqu'aux grands élevages commerciaux en 1967.

L'élevage en grand a donné des résultats tout d'abord dans des viviers intérieurs, en utilisant comme aliment des cultures de diatomée Skeletonema costatum pour le stade zoé, des nauplii Artemia pour les stades mysis et post-larvaire, et de la chair de "clam" hachée pour les jeunes. L'emploi de grands viviers extérieurs remplis d'eau de mer naturelle additionnée de sels nutritifs, a permis de développer considérablement l'ampleur des élevages et d'abaisser les coûtsde production. La poussée de phytoplancton rend inutile la culture à part des diatomées; en outre, le développement considérable du zooplancton naturel et du benthos fait qu'il n'est plus nécessaire d'ajouter que des quantités relativement faibles d'Artemia et de chair de "clam".

La recherche vise actuellement en grande partie à trouver, pour l'alimentation de jeunes crevettes, des aliments autres que ceux qui peuvent servir à la consommation humaine.

EL CULTIVO DE CAMARON KURUMA (Penaeus japonicus) EN JAPON

Extracto

Explica el cultivo del camarón Karuma en el Japón desde los primeros intentos que se hicieron para criar Penaeus japonicus en el laboratorio, en 1933, hasta la producción comercial en gran escala practicada en 1967.

Donde primero se consiguió críar con éxito, en gran escala, fue en depósitos interiores, utilizando cultivos de la diatomea Skeletonema costatum como alimento de las fases zoé; Artemia nauplii para las fases mysis y poslarvales, y carne de almeja triturada para las fases juveniles. La escala de las operaciones se ha aumentado grandemente, disminuyendo el costo de la producción mediante el empleo de grandes depósitos exteriores llenos de agua del mar natural, a la que se añaden sales nutrientes. La consiguiente floración de fitoplancton hace innecesario el cultivo por separado de diatomeas, desarrollándose en grado considerable el zooplancton y bentos silvestre, por lo que solo es necesario añadir cantidades relativamente pequeñas de Artemia y de carne de almejas.

Las investigaciones actuales se dirigen, en gran parte, a la obtención de alimentos adecuados, excluidos los que podría emplear el hombre para los camarones juveniles.

1 INTRODUCTION

The culture of Kuruma shrimp (Penaeus japonicus) in Japan began in July, 1933 when for the first time I succeeded in the artificial spawning and hatching in a culture tank. Since then 35 years have passed. During these years there occurred World War II and my work has taken many turns and twists, nevertheless, I have continued the experiment of Kuruma shrimp culture up to the present.

Now there are 11 management units of Kuruma shrimp culture in Japan. They are mainly in the Seto Inland Sea and produce 200 tons of shrimp annually. I have been favored with the assistance and cooperation of a great many people in my study on shrimp culture in Japan, but in this paper I should like to mention the names of only those persons who have given me specially valuable advice and cooperation in this study.

2 HISTORY OF RESEARCH ON KURUMA SHRIMP

My research work on Kuruma shrimp for the past 35 years from 1933 through 1967 can be divided into 5 periods.

2.1 Period I (From 1933 to 1940)

As stated above, the first time I succeeded in the artificial spawning and hatching of Kuruma shrimp was in early July 1933. In the first attempt, however, because the food of the shrimp in the zoeal stages was unknown, the majority of the larvae died, and only a few of them survived until after their mysis stage. The survival rate of the shrimp has been improved by continued experiment year after year, and in 1940 I succeeded to grow the shrimp to marketable size. The number of shrimps of commercial size, however, was very small and it was far from artificial culture on a commercial basis. These eight years were characterized by difficulties in feeding the shrimp in the zoeal stages.

The laboratory was located in Senzoku Island, Amakusa Archipelago, Kumamoto Prefecture, from 1933 to 1934, then at Misumi, tip of the Uto Peninsula, Kumamoto Prefecture, from 1934 to 1936, and it was removed to Aio, Yamaguchi Prefecture, from 1936 to 1942.

2.2 Period II (From 1941 to 1942)

It was found in early 1941 that a diatom, Skeletonema costatum, provided suitable food for zoeal shrimp. With regard to the pure culture method of S. costatum I was taught by Dr. Yoshiyuki Matsue, at the suggestion of Dr. Ikusaku Amemiya, my respected teacher of Tokyo University. I should have taken many more years to find out S. costatum as a suitable food for zoeal shrimp if I had not been favored with the cooperation of the two professors. In this period Dr. Hiroshi Kasahara and Dr. Kasio Ota worked very hard as my assistants.

As already mentioned, almost all larvae of Kuruma shrimp died during the zoeal stages and less than one percent of them metamorphosed into the mysis stages. However, by feeding them with S. costatum in the zoeal stages, it became possible to rear more than 30 percent of them to the mysis stage. Such increased survival rate of shrimp larvae made me optimistic. It was 8 years since I succeeded in the artificial spawning and hatching of Kuruma shrimp. In 1942, again I repeated the experiment of feeding S. costatum during the zoeal stages, but unfortunately on July 16, 1942 my laboratory at Aio was totally destroyed by a high tide caused by a typhoon. Most of the experimental data and reference materials collected for many years were washed away by the high tide. However, a bright spot in the misfortune was that the draft of my third paper (Hudinaga, 1942) was in a printing office in Tokyo and escaped loss.

2.3 Period III (From 1942 to 1949)

The year of the destruction of my laboratory at Aio, 1942, was the second year of the second world war in which Japan was involved. There was a shortage of human food, and there was a general feeling that the study of luxury foods such as Kuruma shrimp should not be continued. Such public opinion made it impossible to rebuild the laboratory.

At that time I was also studying the attachment mechanism of the barnacle (Balanus), work which was subsidized by the Navy. I built a laboratory at Toyohama, tip of Chita Peninsula, Aichi Prefecture, chiefly for barnacle study, but my study on Kuruma shrimp was continued in it as before. The second world war came to an end in 1945 during my stay at Toyohama.

For several years after the second world war the Japanese people suffered very much from shortage of food and I could not devote myself to work on Kuruma shrimp. I spent my time studying literature on the life histories of marine animals. So the several years after the second world war were the most fruitless in my entire period of study of Penaeus.

2.4 Period IV (1949 - 1959)

In February 1949 I was appointed the Chief of the Research Division which was newly established in the Fisheries Agency. My main task was to rebuild and enlarge the national fisheries research organizations devastated by the war, but I could not forget the shrimp study even in the very busy office. Every Sunday I used to make field observations on shrimps on the beach of Chiba Prefecture bordering on Tokyo Bay.

It had been found before the war that S. costatum was a suitable food for zoeal shrimp. In the stages from mysis to early post-larvae, it was possible to feed the larvae on fine grains of fish meal, but the result was not satisfactory. I cherished the hope to repeat the prewar experiment and, if possible to carry out a large scale experiment. In the years after the War the supply of goods gradually increased and social conditions improved. In the summer of 1955 I established a small laboratory at Kisarazu, Chiba Prefecture, at my own expense and resumed the experiment on Saturday afternoons, Sundays and holidays.

As Chief of the Research Division in the Fisheries Agency, I was involved in international negotiations and conferences on Fisheries, and visited Canada, U.S.A., U.S.S.R., Italy and Switzerland. Through these trips abroad I got valuable information on shrimp culture, and particularly during the fur seal negotiations in Washington, between Japan, U.S.A., Canada and U.S.S.R., which extended from November 1955 to April, 1956. This meeting was not held on a daily basis, and sometimes it was adjourned a week or ten days. I visited various institutes while the meeting was adjourned.

One of these visits was to the Marine Laboratory of North Carolina University at Newport, where they were rearing Schizopoda using nauplii of brine shrimp as food. The idea came to me that nauplii of brine shrimp might be used as food of penaeid shrimp from mysis to early post-larval stage. I began rearing brine shrimp at the hotel, Washington D.C.. It was very hard to get sea water in Washington D.C., but the sea water was transported to my hotel every two days through the kindness of Dr. L.A. Walford.

In the summer of 1956 nauplii of brine shrimp were given to mysis larvae or early post-larvae of shrimp and this was found to produce good results, as expected. But this was a very small scale experiment. I borrowed 3000 m^2 of land in the Onuki coast, Chiba Prefecture, in 1957 and set up a laboratory and a culture farm of bigger size than before. With these facilities it became possible for the first time to build a pure culture tank for S. costatum of 2 m x 1 m x 1 m, a spawning and hatching tank of the same size and various culture ponds of different sizes. These facilities were used as the basis for construction of Takamatsu Culture Farm. In 1958 for the first time 10 kg of shrimps of marketable size were produced.

I resigned from the Fisheries Agency in October 1959 after 10 years and 6 months service. It was feasible neither to carry out free research study not to manage a large culture farm while I was in government service.

2.5 Period V (1959 to present)

I established a company as soon as I resigned my office in the Fisheries Agency and set up a culture farm of commercial scale in the disused salt farm, Takamatsu. In the actual management of the culture farm of commercial size, everything did not go so well as in the laboratory.

The result worthy of special mention from 1959 up to present was that a large amount of cheap fry (the first requisite for shrimp culture) was made available. Fry culture technique has continued to develop and at present it would be possible to produce more than one thousand million fry annually if there were enough demand.

However there remain many problems yet to be solved concerning the food from fry to adult stage, which is the second requisite for shrimp culture. As will be mentioned later, foods for shrimp culture are at present bivalves, such as short-necked clams, shrimps and fish. These should be used primarily for human food and not for shrimp culture. The amount of food necessary for 1 kg shrimp production is 7 to 10 kg. Accordingly, the more the cultured shrimp production increases, the more the animal protein for human consumption decreases from the view-point of Japan as a whole. Unless this contradiction is solved, there is no possibility of shrimp culture development in Japan. I have been studying to find a food which does not compete with human food and I have had some success in the laboratory, but I have not yet tried a large scale experiment. I am now planning to make a big scale experiment in the summer of 1968, and I am expecting that this problem will be solved to some extent during 1968.

3 PRESENT KURUMA SHRIMP CULTURE IN JAPAN

Until 1964, for the purpose of spawning, hatching and raising of kuruma shrimp larvae, the following standard method was used. Fill a small tank (2 m x 1 m x 1 m) with filtered sea water in an almost dark room, put the mature female shrimp into this tank, and let her spawn. Give as food mainly diatoms like pure cultured S. costatum etc., after the larvae have metamorphosed into zoeas. Give nauplius of brine shrimp after the larvae have metamorphosed to the mysis stage. Give finely crushed meat of short-necked clams for several days after the larvae have transformed into post-larvae. However, as mentioned before, late in June 1964 a method for the mass culture of larvae was developed, and the culture method of larvae became entirely changed. Thereafter this new method was further improved and now it has become easy to get 1,500,000 fry in average in a concrete tank, 10 m x 10 m x 2 m in size.

The following account of the 1964 experiment is adapted from Hudinaga and Kittaka (1967). [1]

3.1 The 1964 experiment

3.1.1 Limitations of earlier method The larvae of the Kuruma prawn in the nauplius stage are sustained nutritionally by the yolk which is carried within their body and the actual consumption of food begins with the zoea stage (Hudinaga, 1935). One of the foods most suitable for the zoea stage is the cultured diatom, S. costatum (see Hudinaga, 1942). However, due to the difficulty of maintaining the cultured diatoms during certain seasons, bivalve eggs and larvae or a benthic diatom which grows in special ponds having a double bottom structure have been substituted (Hudinaga and Miyamura, 1962).

One of the characteristics of the conventional method of raising the larvae on these foods is that the culturing of food, and the collection of it, is done separately from raising the larvae, and the prepared foods are later fed to the larvae in the culture tank (Hudinaga and Kittaka, 1966).

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[1] The editors are grateful to the Plankton Society of Japan for permission to republish this account.

This method is relatively costly and not well suited to production on a very large scale. Dr. Kittaka and I therefore conducted experiments in order to solve the problems of mass production and lower cost by employing a larger culture tank and applying an extremely simple method to produce a large number of young prawns in a single operation.

The preparatory experiment and study were done in September of 1963 at the Kuruma Prawn Farming Co. Ltd., Ikushima, Takamatsu, and this was followed by full scale experiments and study at the Setonaikai Fishery Development Co. Ltd., Aio, Yamaguchi, from July through November 1964. The following reports are based on the results of the 1964 experiments.

3.1.2 Method The culture tanks used for this experiment were 12 salt concentration tanks (Tanks No. 1-12) at the disused salt field located in Hanaga, Aio-cho, Yoshikigun, Yamaguchi-ken. These tanks were equipped with apparatus for supplying water and aeration for experimental use. The dimensions of these culture tanks were 10 m x 10 m x 2 m, and they were constructed on concrete slabs outdoors. The floors of the culture tanks Nos. 1-8 had gradients toward the drainages, but the culture tanks Nos. 9-12 had level floors.

Twenty aeration pipes were used for each culture tank. Tanks Nos. 1-8 were provided with sufficient aeration but tanks Nos. 9-12 received insufficient aeration due to the narrowing of the main distribution pipe.

The parent prawns used for the experiment were selected from the catch from nearby Aio Bay. They were placed in the culture tank overnight for spawning and, as a rule, they were removed on the following day.

The water supply for the breeding was obtained from Aio Bay and was filtered through 80 to 100 mesh screen net. From the time of the placement of the parent prawn in the culture tank to the early part of the post-larvae stage, a period covering 15 to 20 days, the water was not changed, but after this period, 1/5 of the total amount of water was changed each day.

In this research project no provision for using the special diatom culture tanks (as used in the past conventional method) were made, but attempts were made for the propagation of plankton-like diatoms in the culture tanks by adding nutrient salts. The nutrient salts used were potassium nitrate and potassium phosphate. The eggs of Artemia or clam meat were fed according to the stage of larval development.

The approximate number of larvae in the culture tanks, in each stage, was estimated by counting the number of larvae in 1 litre of water sampled from several locations in a culture tank.

At the time of the final collection, the young prawns were placed in buckets, several thousand in 10 or 12 l of water in each bucket. A sub-sample of 0.2 l was taken from each bucket, after stirring, to obtain a final estimate of numbers. This final figure was more accurate than that obtained from samples from the culture tanks.

3.1.3 Results The records of the hatching and development of the larvae appear in Table I. In the case of tanks Nos. 9-12, the production of the young prawns was very low in five of the six experiments. This was probably due to insufficient aeration and to the flat bottom of the tank becoming covered with dead plankton and waste food.

Of the 22 tests which were conducted in tanks Nos. 1-8, eight were discontinued because of poor production of larvae. Four tanks out of the 14 which were continued produced less than 300,000 young prawns. Three of these four tanks were initial test tanks, in which the experiments were preparatory. The remaining test tank contained post-larvae which were kept in the tank over 100 days. Without counting these exceptional cases, the production of the young prawns per tank was 800,000 to 1,250,000, with an average count per

TABLE I

Records of breeding experiments in an outdoor concrete tank, 10 m x 10 m x 2 m, using unfiltered sea water

No. of ex-periment	No. of tank	Date of placing mature female prawn	Number of mature female prawn placed	Estimated number of larvae (x 10^3)					Survival rate from nauplius (%)	Stage of fry (P_n)*	Stage at which experiment was closed
				Nauplius	Zoea	Mysis	Post larva	Fry			
1	4	6.30	18	1,500	230	300	150	209	13.9	P_{27}	
2	5	6.30	44	3,900	1,800	1,430	770	420	10.7	P_{30}	
3	8	7. 1– 2	39	3,900	1,560	750	1,010	710	18.2	P_{28}	
4	2	7. 3– 4	36	3,600	1,800	2,030	1,730	1,001	27.7	P_{30}	
5	7	7. 5– 6	43	1,350	700						No. of P_{11}: 300 x 10^3
6	1	7. 7–10	55	3,000	2,550						Z_3
7	6	7.11–12	70	3,900	3,210	2,100	900	807	20.7	P_{40}	
8	3	7.13–15	28	5,220	980	690	600				No. of P_6 : 500 x 10^3
9	1	7.16–17	89	11,400	6,150	1,500	4,100	1,137	9.9	P_{33}	
10	11	7.18–20	62		1,200	990	600	349		P_{35}	
11	10	7.21–23	103	6,180	1,140	900					No. of P_{21}: 200 x 10^3
12	7	7.26	31	3,600	2,100	1,430	990	1,251	34.7	P_{33}	
13	3	7.29	53		450	390	150				No. of P_{11}: 200 x 10^3
14	9	8. 1	51	1,430	900	600	0				P_1
15	4	8. 6	198		0						No. of P_4 : 10 x 10^3
16	5	8. 8– 9	117	7,350	6,990	3,300	1,500	892	12.1	P_{74}	
17	8	8.10–11	109	6,300	3,150	3,600	830	770	12.2	P_{106}	
18	2	8.14–15	58	3,900	2,400	2,400	1,200	884	22.7	P_{103}	
19	3	8.19–20	36	1,350	750						No. of P_{11}: 300 x 10^3
20	4	8.20	80	2,100	1,500		900	1,100	52.3	P_{63}	
21	10	8.23	48					168		P_{63}	
22	1	8.30	74	1,130	900	680	150	859	76.3	P_{54}	
23	6	9. 1– 2	67	2,250	1,800	1,800	990	809	35.9	P_{50}	
24	11	9. 4	34	1,290	2,700	380		826	64.0	P_{49}	
25	7	9. 6	41	1,200	230						No. of P_7 : 200 x 10^3
26	3	9. 9	30	1,650	1,730			1,202	72.8	P_{44}	
27	12	9.15–16	17		1,500			151		P_{39}	
28	7	10.24–29	38			9					Mostly zoea

* Pn = n days after metamorphosis to post-larva

tank of 1,000,000. However, the duration of the rearing period was 50 days, a longer period than the average for conventional methods. If the young prawns are harvested with a rearing period of about 20 days, as in the conventional method, a further increase in production can be predicted.

3.1.3.1 Relation between number of parent prawns and number of young produced A female prawn will release nearly all her eggs within two days. The number of parent prawns which produced the larvae is shown in Table I. The relationship between the number of prawns and the number of larvae produced is shown in Fig. 1. This relationship is not linear. That is to say, it is necessary to have more than 30 mature female prawns to produce 1,000 x 10^3 young prawns, and yet increasing the number of mature females to more than 100 has little effect on the number of young prawns produced. In this experiment about sixty percent of the females actually spawned.

3.1.3.2 Effect of environmental conditions on hatching and development of larvae The larvae of the Kuruma prawn are sensitive to changes in environmental conditions in their nauplius and zoea stages and are especially susceptible in the zoea stage. Table II shows the water temperatures and weather conditions during early stages of development of the larvae.

Water temperatures, from the later part of July to the middle of August, averaged about 29°C at 6 a.m., and the depth of the culture tank was sufficient to keep the maximum daytime water temperature under 31°C. There were no observations of critical effects on larvae caused by increases in water temperature.

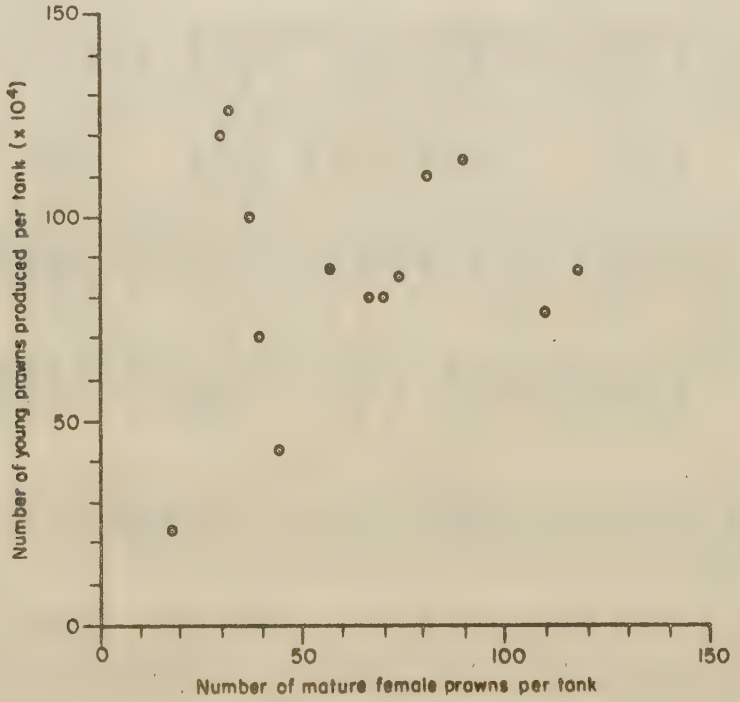

Fig. 1. Relation between the number of mature female prawns and the number of young prawns produced per tank.

The good results of spawnings in the latter part of August may have been due to the post-larvae developing at a comparatively lower temperature, resulting in a higher survival rate. Where the spawning took place at the end of September the larvae did not reach the mysis stage due to the lower temperature during the zoea stage.

The zoea stages were thought to be sensitive to decreases in the specific gravity of the water and to direct sunlight, therefore, the rearing of the larvae in the zoea stages has usually been conducted in indoor culture tanks. Among the outdoor experiments there were five which had one or more rainy days through the nauplius and zoea stages, and eight had fine weather through all the stages. In these cases, only one experiment was discontinued due to the poor survival of larvae. Therefore, the rearing of the larvae in outdoor culture tanks was not affected by the one day of rainfall nor by the successive days of strong sunlight.

TABLE II

Some environmental conditions during breeding experiments

No. of experiment	Average water temperature during nauplius and zoea stage (°C)	Weather condition during nauplius and zoea stage		
		B**	C**	R**
1	27.6	6		
2	27.7	6		
3	27.8	6		
4	28.4	5	1	
5	28.0	5	1	
6	27.5	5	1	
7	27.2	5	1	
8	28.2	5	1	
9	27.0	3	3	
12	29.0	6		
13	28.7	5	1	
15	29.7	6		
16*	30.5	5		
17*	29.7	5		
18	29.6	6		
19	28.0	2	3	1
20	28.4	2	3	1
22*	28.4	3		2
23*	28.2	2	1	2
25*	26.9	4	2	
26	26.8	3	2	1
28	20.8	3	3	

* Owing to the good breeding condition, zoea passed into mysis within 3 days

** B: Number of bright days
C: Number of cloudy days
R: Number of rainy days

3.1.3.3 Fertilization with nutrient salts The inorganic nutrient salts dissolved in the water of Aio Bay are at about the level N: 100-200 mg/ton and P: 15 mg/ton, and consequently, in certain conditions the propagation of diatoms could be attained with this seawater as it is. However, in order to expedite the propagation and to maintain the desired propagation level of diatoms for a longer period, supplementation of the nutrient salts is necessary.

The amounts of fertilizer used, as shown in Table III, differed, depending upon the days and the tanks, since the experiments were conducted under trial conditions. In the final analysis fertilization with 200 g of potassium nitrate and 20 g of potassium phosphate, dibasic, per day per tank, from the day after hatching, became the standard quantity. It provided 180 mg of N and 20 mg of P per day for every ton of water.

Although most of the diatoms produced by adding fertilizers will be consumed by the larvae in the zoea stages, a considerable amount of diatoms will also be consumed by zooplankton which enters the culture tank through the filtering screens. Furthermore this zooplankton can be used as food for larvae after the mysis stages. From the above point of view, the addition of nutrient salts has a great significance in culturing young prawns.

TABLE III

Amount of fertilizer added and foods given during breeding experiments

No. of experiment	Amount of fertilizer added in kg		Amount of foods given in kg	
	Potassium nitrate	Potassium phosphate, dibasic	Artemia egg*	Baby neck clam meat
1	1.10	0.11	0	7.7
2	1.90	0.19	2.40	52.6
3	1.75	0.175	4.16	47.3
4	1.05	0.105	5.10	88.6
5	1.00	0.10	-	-
6	0.40	0.04	-	-
7	1.75	0.175	7.64	270.3
8	1.90	0.19	-	-
9	5.20	0.52	7.60	246.1
12	5.00	0.50	1.30	224.6
13	1.40	0.14	-	-
15	0.60	0.06	-	-
16	7.92	0.792	10.80	616.5
17	7.24	0.724	7.30	838.6
18	8.10	0.81	10.50	730.5
19	2.00	0.20	-	-
20	6.75	0.657	17.70	526.5
22	5.40	0.54	10.50	418.5
23	5.40	0.54	8.50	356.5
25	2.00	0.20	-	-
26	4.88	0.488	11.70	250.5
28	1.60	0.16	-	-

* Canadian product. Hatching rate: about 40 percent

A week after the larvae have reached the post-larva stage, part of the population of diatoms which have been propagated in the tank will be replaced by pigmented protozoa, green algae, bacteria, etc., but the regular addition of fertilizers brings better results in culturing the larvae.

3.1.3.4 *Feeding of Artemia* *Artemia* are considered the best food for the mysis larva and the pelagic post-larva (Hudinaga and Miyamaura, 1962; Hudinaga and Kittaka, 1966). However, the use of *Artemia* was confined to the pelagic period of the post-larva in this experiment.

The amount of *Artemia* fed into each individual culture tank is shown in Table III and the relationship between this and the number of larvae produced is shown in Fig. 2. Examination of the culture tanks which produced larvae of more than 800 x 10^3 showed that the highest results were achieved even with the minimum amount (1.3 kg) of *Artemia*, and that increasing the amount of *Artemia* to 17.7 kg resulted in no increase in prawn production.

In an experiment done in three smaller containers, the concentration of the larvae was kept constant (10 post-larvae per liter), and *Artemia* was added at the rate of 250, 500 and 1,000 nauplii per l per day. The results showed that there was no difference in the growth and survival rate, in spite of the fact that the post-larvae consumed all of the varying quantities of *Artemia* nauplii which were added to the different containers (Kittaka, unpublished data).

The experiments indicated that there is no significant difference in the growth and survival rate of the post-larva within the range of 0.75 to 3.0 kg of *Artemia* per culture tank per day. Furthermore, it is a significant fact that almost the same production level was attained even in the culture tanks which were fed with lesser amounts of *Artemia*, except three culture tanks in the initial experiments.

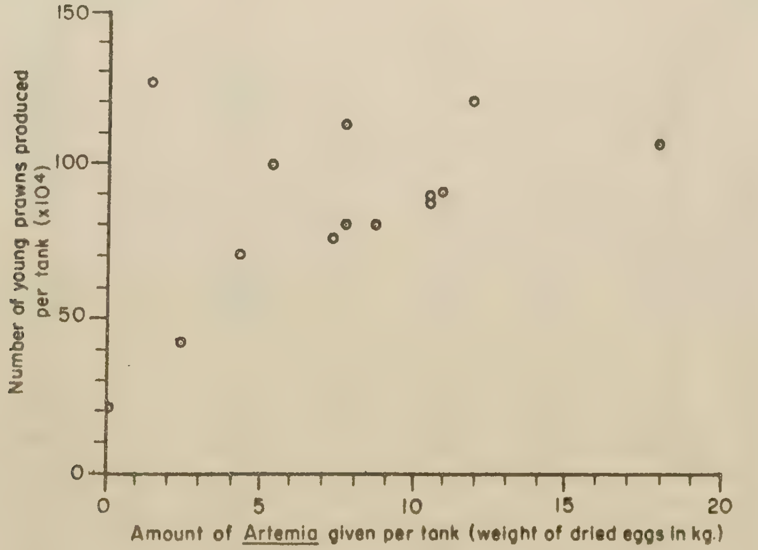

Fig. 2. Relation between the amount of *Artemia* given and the number of young prawns produced per tank.

Artemia used in this experiment is a Canadian product and its hatching rate is about 40 percent.

Apparently, as mentioned above, zooplankton such as copepods, etc., which feed on the micro-diatoms which in turn multiply in the waters enriched with N and P, make up an important part of the food of the early stage of post-larvae.

3.1.3.5 Feeding of baby neck clam Baby neck clam is one of the most suitable foods for the post-larva during the bottom living period (Hudinaga and Miyamura, 1962; Hudinaga and Kittaka, 1966). The clam meat is also suitable for planktonic post-larva because when it is crushed into small pieces it has a certain degree of bouyancy (Hudinaga and Kittaka, 1966). In this experiment, clam meat was used throughout the entire post-larval period.

The amount of baby neck clam used for feeding is shown in Table III, and the relationship between the total amount of food and the number of larvae produced up to the P_{21} stage is shown in Fig. 3. The production of a million larvae was obtained by adding only 18 kg up to the P_{21} stage, but the production did not increase as expected when the amount of food was increased to 100 kg.

Some of the diatoms produced by fertilization with N and P were not consumed by the larvae or the zooplankton and gradually precipitated along with some undigested food on the bottom of the tank. The amount of sedimentation gradually increased as the larvae grew, and by the time they entered into the post-larva stage many protozoa and micro-organisms, which propagated secondarily among the sediment, and many benthic macro-organisms, such as polychaets, barnacles, bivalves, etc. which also entered the tank as plankton, created an environment on the bottom of the culture tank which was vital to the feeding of the larvae. This sediment and the number of benthic organisms in the bottom of the tank began to decrease about the time the post-larvae entered the P_{10} stage, which is a bottom-living stage. After the P_{20} stage, only larger sized polychaets and mature barnacles remained on the bottom of the culture tank. This is clear indication that the bottom-living post-larvae were feeding on the sediment and the benthic organisms. Table IV shows the relationship between the total weight of the young prawns in each individual culture tank (W), which is based on the harvested numbers and an average weight of larvae, and the amount of the clam meat fed up to the time of harvesting (F).

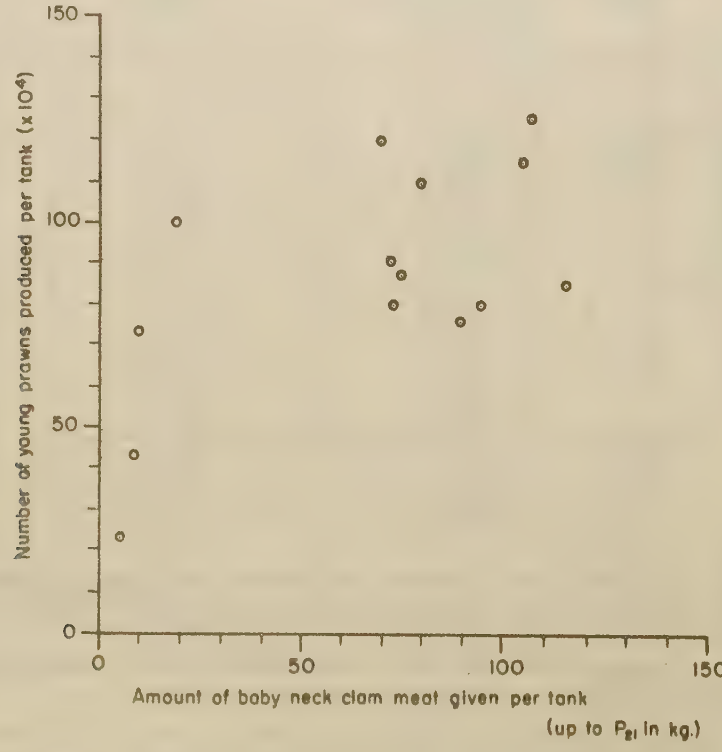

Fig. 3. Relation between the amount of baby neck clam meat given and the number of young prawns produced per tank.

The comparatively low yield of 200 x 10^3 young prawns per tank was produced for an F/W value of only 2.4. It seems likely that a similar production could be obtained relying entirely upon the natural supply of food.

3.1.4 *Discussion* In the conventional method, cultured diatom, *Skeletonema costatum*, was fed to the larvae in the zoea stages and *Artemia* after the mysis stage, especially in the post-larva stage. However, through the results of our experiments in supplying the larvae with various foods in each stage of development, we have found many kinds of food which can be used as substitutes (Hudinaga and Kittaka, 1966).

After finding that untreated sea water and direct sunlight produced a fairly good crop of diatoms, we have done further experiments as follows. We have used untreated sea water for the culture tank, increased illumination for the indoor type of culture tank, and we have reared the entire developmental stages in the outdoor type of culture tank (Hudinaga and Kittaka, 1966). Each experiment was successful. As a result of these series of experiments, we now conduct tests in a larger culture tank. It has proved possible to produce an average of 1,000 x 10^3 young prawns in a tank of dimensions 10 m x 10 m x 2 m (depth).

TABLE IV

Relation between total weight of fry produced and amount of baby neck clam meat given

No. of experiment	Number of fry produced (x 10^3)	Average body weight (g)	Days elapsed after moult to 1st post-larva	Total weight of fry (kg) (W)	Amount of baby neck clam given (kg) (F)	F/W
1	209	0.015	26	3.13	7.66	2.4
2	420	0.010	26	4.20	48.4	11.5
3	710	0.009	27	6.40	47.3	7.4
4	1,001	0.009	27	9.00	45.6	6.2
5	-	-	-	-	-	-
6	-	-	-	-	-	-
7	807	0.028	40	22.60	270.3	11.9
8	-	-	-	-	-	-
9	1,137	0.025	34	28.43	246.1	8.5
12	1,251	0.013	33	16.26	224.6	13.7
13	-	-	-	-	-	-
15	-	-	-	-	-	-
16	892	0.052	72	46.37	594.5	12.8
17	770	0.074	71	56.98	603.6	10.6
18	884	0.041	67	46.24	497.5	10.8
19	-	-	-	-	-	-
20	1,100	0.041	61	45.10	504.5	11.2
22	859	0.050	50	42.45	391.5	9.2
23	809	0.031	49	25.08	345.5	13.7
25	-	-	-	-	-	-
26	1,202	0.016	42	19.23	227.5	13.0
28	-	-	-	-	-	-

The new method and the conventional method of rearing the larvae in the culture tank differ in several ways.

First of all, the new method does not involve culturing the planktonic food nor its collection in a separate culture tank but relies on the direct application of fertilizer into the culture tank. In the new method, the propagation of phytoplankton takes place first then the zooplankton (copepods) follows, and among the sediment on the bottom the increase and growth of the benthic organisms takes place.

Secondly, the new method employs fewer female prawns and in turn it provides a considerably lower density of early stage larvae. Regarding the ten tanks which produced more than 800 x 10^3 larvae, the average figures per tank were :

Number of female prawns	69
Number of hatched nauplii	4,100 x 10^3
Number of young prawns produced	1,000 x 10^3

In the conventional small culture tank, the capacity of which is 1/100 that of the larger tank, the average figures per tank are:

Number of female prawns	2-5
Number of hatched nauplii	200-400 x 10^3
Number of young prawns produced	10 x 10^3

Multiplying these figures by 100 for comparison with those for the larger tank gives 200-500, 20,000-40,000 x 10^3 and 1,000 x 10^3. That is to say, the new method, in comparison with the conventional method, requires 1/5 to 1/10 the number of female prawns per unit volume of the water, and produces 1/5 to 1/10 the number of nauplii, yet the survival rate from nauplii to young prawns is 24%, which is far better than the conventional figure of 2.5 to 5%. In both cases, the resulting number of young prawns per unit volume of water is about the same.

Thirdly, in the new method, the larvae are more or less dependent on natural food, which is produced by the addition of fertilizers all through the rearing period, therefore the addition of artificially prepared foods such as Artemia and clam meat can be reduced drastically. In some cases it may be possible to rear young prawns entirely on natural foods but some addition of food is advisable for higher densities of larvae. Thus to produce 1,000 x 10^3 young prawns 5 kg of Artemia eggs (Canadian product with 40% hatching rate) and 80 kg of baby neck clam meat will be satisfactory. In the conventional method, the standard procedure was to provide 5 g of Artemia eggs (Californian product with 80% hatching rate) each day for seven days for every 10,000 early stage post-larvae. Since the survival of post-larvae averages 40%, the necessary amount of Artemia to produce 1,000 x 10^3 young prawns when the Californian product is used is 8.75 kg. The equivalent amount of Canadian Artemia eggs is 17.5 kg.

According to the conventional method, the amount of the baby neck clam per day to produce 10,000 young prawns averages 70 g for the period from P_4 to P_{11} and 140 g for the period from P_{12} to P_{20}. Therefore, the total amount of the clam meat given up to the 20th day as post-larvae is approximately (70 x 8) + (140 x 9)=1,820 g, and the amount of clam meat necessary for every 1,000 x 10^3 young prawns would be 180 kg. Therefore, in the new method, the necessary amount of Artemia to produce a unit number of young prawns is reduced to 28% and baby neck clam is reduced to 44%.

Fourthly, the new method eliminates such processes as the cultivation and collection of diatoms, the frequent feedings and the stirring which was required for even distribution of food, etc.

According to Dr. Kittaka's experience, the personnel necessary to produce 10,000 x 10^3 of young prawns per month is one technician, one male laborer and two female helpers.

The above mentioned series of experiments has succeeded in reproducing the natural development of larvae, as in the ocean, within the environment of the artificial culture tank. It has achieved true mass production of young prawns in the culture tank and reduction of production costs.

One great disadvantage of the new method is that the quality of water in the culture tank tends to be lowered due to the use of raw sea water passed through only a coarse filter.

As shown in Table I, two out of the eight culture tanks in which the experiments were discontinued (excluding No. 9-12 culture tanks) showed a poor hatching rate to the nauplius stage, and the other six culture tanks had a high mortality rate in the early zoea stage. In both cases, the quality of water affected the results. The use of sand filtered sea water, as used in the conventional method, could obtain a more consistent quality of water, but the propagation of natural foods by fertilizing the water with N and P could not then be obtained and the advantages of the new method would be reduced to half.

In any case, this would have little influence on the total production of young prawns, since the culture tank which shows poor production can usually be detected in an early zoea stage, within a short period of stocking it.

The outdoor culture tanks used for these experiments were exposed to direct sunshine in summer, with resulting increases of temperature, and they experienced decreases of specific gravity due to rainfall, and we were concerned about the effects on the larvae. There were no records of critical cases which might have been a direct result of these conditions.

Since the new method introduces the maximum use of natural conditions, local and seasonal influences upon the cultivation of prawns will be unavoidable. The combined use of the new and the conventional methods could be recommended in some local cases. At present we are conducting experiments on the new method of hatching and raising of young prawns at sites other than the coastal area of Seto Inland Sea. After gathering all the materials and data of the experiments, the problems presented above will be re-evaluated.

4 RAISING SHRIMP FROM FRY TO ADULT STAGE

In Japan, shrimp ponds for culturing from fry to adult are now mostly in disused salt farms. The area of one culture pond is usually 10,000 m^2 to 30,000 m^2, and ranges from 2,000 m^2 to 100,000 m^2. The depth of the pond is about 1 to 2 meters. The pond is connected to the sea, so that it is partly drained during the ebb tide and floods during the flood tide. In the Seto Inland Sea there are regular high and low tides twice a day, so the pond is flooded and drained twice a day. The exchange of water is greatest at spring tides.

The best season for releasing fry in the culture pond is from early May to mid-June, and the fry at that time weigh 0.01 - 0.02 g. After about 6 months, fry grow into shrimp of 15 - 25 g in weight, which is their marketable weight. Weight of shrimp per 1 m^2 is 200 - 300 g, that is 10 - 20 shrimp per 1 m^2.

It is, of course, impossible for all the fry released in the pond to grow into adult shrimp. The fry in the pond decrease in number either by their feeding on each other or by predation, and their survival rate during the 6 months is 30 to 50 percent. Therefore the number of fry to be released should be decided by taking the above survival rate into consideration.

The foods for shrimp culture in Japan, as already mentioned, are short-necked clams, shrimps, fish and so on. As these animal protein sources are potential human food, Kuruma shrimp culture in Japan cannot be said to be very productive, but we may be proud of the invention of the mass production method of shrimp fry.

Now the study on food for shrimp culture is going on and I expect this food problem will soon be solved. At that time the method of Kuruma shrimp culture in Japan will undergo a complete change. I hope to explain the rearing method from fry to adult in detail after the food problem has been solved. At present, only the outline method is described in this report.

I should like to report experiments on the effect of the difference of food quality on the survival rate of shrimp and on the potential increase of production per unit area. It is to be noted that these were only small scale experiments and not on a commercial basis. These experiments were mainly conducted by Mr. Isamu Ando and Mr. Isao Ishida.

4.1 Comparative experiments with a variety of foods

In order to determine differences in growth and survival rates by feeding a variety of foods, the following experiments were conducted, testing the following foods:

1. Frozen small shrimp;
2. Crushed neck clam meat which was washed to separate the shell and meat;
3. Crushed neck clam meat without washing before separation of shell and meat;
4. A mixture of 80 percent frozen small shrimp and 20 percent by weight of crushed neck clam.

The experiments were conducted in a tank of 10 m x 10 m x 2 m (depth) and of concrete structure. One tenth of the total bottom area of the tank was covered with sand of 10 cm thickness, and a sufficient amount of aeration to keep a good oxygen content was applied. Excess food was provided.

The young shrimp which were used in the experiment were all offspring from the same female shrimp. The average weight of the young shrimp was 0.11 g at the beginning of the experiments. Each experimental tank contained 4,000 young shrimp; therefore the total weight of young shrimp in each tank was about 0.44 kg, with the young shrimp distributed about 40 per square meter.

The experiments were started on 10 June 1966 and completed on 9 November 1966 (five months). The data are summarized in Table V and water temperatures are given in Table VI.

TABLE V

Results of comparative experiments with a variety of foods

TANK (1) FROZEN SMALL SHRIMP

After	1 Month	2 Months	3 Months	4 Months	5 Months	Remarks
No. of Shrimp	3,320	2,640	1,960	1,280	670	
Average Wt. (g)	0.75	4.15	10.6	14.7	22.6	
Total Wt. (kg)	2.49	10.96	20.78	18.82	15.2	152 g/m^2*
Survival Rate (%)	83.0	66.9	49.0	32.0	16.8	
Wt. Coefficient	27.3	23.6	25.5	—	--	51.4**

TANK (2) CRUSHED NECK CLAM-WASHED

After	1 Month	2 Months	3 Months	4 Months	5 Months	Remarks
No. of Shrimp	3,864	3,732	3,600	3,468	3,338	
Average Wt. (g)	1.69	7.24	14.3	17.9	22.9	
Total Wt. (kg)	6.53	27.0	51.5	62.1	76.6	766 g/m^2*
Survival Rate (%)	96.6	93.3	90.0	86.7	83.5	
Wt. Coefficient	9.18	9.8	12.4	24.6	13.3	13.3**

TANK (3) CRUSHED NECK CLAM - UNWASHED

After	1 Month	2 Months	3 Months	4 Months	5 Months	Remarks
No. of Shrimp	3,872	3,748	3,620	3,492	3,363	
Average Wt. (g)	2.02	7.78	14.9	19.5	24.4	
Total Wt. (kg)	7.82	29.2	53.9	68.1	82.3	823 g/m^2*
Survival Rate (%)	96.8	93.7	90.5	87.3	84.1	
Wt. Coefficient	6.44	11.1	13.3	18.4	11.9	12.7**

TANK (4) FROZEN SMALL SHRIMP - 80% AND NECK CLAM - 20%

After	1 Month	2 Months	3 Months	4 Months	5 Months	Remarks
No. of Shrimp	3,872	3,744	3,612	3,484	3,353	
Average Wt. (g)	1.61	7.92	14.55	20.4	26.4	
Total Wt. (kg)	6.23	29.6	52.6	71.1	88.2	882 g/m^2*
Survival Rate (%)	98.8	93.5	90.3	87.1	83.8	
Wt. Coefficient	9.39	8.6	12.5	14.1	9.64	11.0**

* Total shrimp production in five months per unit area

**Food consumption per gram of shrimp during five months

TABLE VI

Average water temperature (°C) for each ten-day period during feeding experiments[1/]

Month	Period	Temperature (°C) a.m.	Temperature (°C) p.m.	Month	Period	Temperature (°C) a.m.	Temperature (°C) p.m.
June	11-20	20.4	20.8	September	1-10	27.4	29.2
	21-30	24.1	25.0		11-20	23.7	25.0
					21-30	20.5	21.9
July	1-10	22.1	22.5				
	11-20	24.2	24.8	October	1-10	19.9	21.2
	21-30	25.4	29.5		11-20	19.3	20.0
					21-30	14.2	16.0
August	1-10	28.3	30.0				
	11-20	28.3	29.8	November	1-10	13.7	15.0
	21-30	27.4	27.6		11-20	13.9	15.5

[1/] In June and July the morning temperature reading was taken at 08.00, in August-November at 05.00. The evening temperature reading was taken at 20.00 throughout.

The results shown in Table V were largely unexpected.

The food used in tank 1 consisted of small frozen shrimp which were thought to be suitable for the shrimp, but the results were unexpectedly poor. Frozen food alone appears to be nutritionally inadequate. In this case, the shrimp became cannibalistic to compensate for the deficiency in nutrition and the resultant survival rate was only 16.8%. Tanks 2 and 3 both were fed with identical clam meat. Results were far superior to those in tank 1. However, in the case of tank 2, the clam meat was washed to separate the meat and the shell. Therefore, some of the soluble protein of the clam meat apparently was washed away, producing a lower quality food than that in tank 3. In tank 4, by using only 20% of freshly crushed clam meat and 80% of frozen small shrimp, results were better even than in tanks 2 and 3.

4.2 Experiments to determine the maximum cultivation density of Kuruma shrimp

The tanks used in this experiment were of the same dimensions as those in the previous experiment (10 m x 10 m x 2 m). The experiment was started on 10 June 1966 and completed on 10 November 1966.

The young shrimp used in these experiments were all offspring from the same female shrimp. The initial average weight of the young shrimp was 0.075 g. Sufficient aeration was applied. Results shown in Table VII, indicate that a concentration of 280 shrimp per square meter is too high.

TABLE VII

Maximum cultivation density of shrimp per unit area

TANK (5) YOUNG SHRIMP $150/m^2$

After	1 Month	2 Months	3 Months	4 Months	5 Months	Remarks
No. of Shrimp	15,000	15,000	15,000	15,000	14,841	
Average Wt. (g)	1.2	4.8	8.6	13.6	16.9	
Total Wt. (kg)	18.0	70.5	129.0	204.0	250.0	2.5 kg/m^2*
Survival Rate (%)	100	100	100	100	98.9	
Wt. Coefficient	6.8	10.2	14.7	10.4	12.2	

TANK (6) YOUNG SHRIMP $280/m^2$

After	1 Month	2 Months	3 Months	4 Months	5 Months	Remarks
No. of Shrimp	27,020	24,360	20,720	17,556	15,000	
Average Wt. (g)	1.1	4.7	9.0	14.0	15.2	
Total Wt. (kg)	29.7	114.5	186.5	254.8	228.0	2.28 kg/m^2*
Survival Rate (%)	96.5	87.0	74.0	62.7	53.6	
Wt. Coefficient	6.6	9.0	16.9	16.6	—	

TANK (7) YOUNG SHRIMP $150/m^2$

After	1 Month	2 Months	3 Months	4 Months	5 Months	Remarks
No. of Shrimp	13,995	13,500	13,005	12,510	12,100	
Average Wt. (g)	1.6	6.1	12.0	17.0	20.8	
Total Wt. (kg)	22.4	82.4	156.1	213.0	252.0	2.52 kg/m^2*
Survival Rate (%)	93.3	90.0	86.7	83.7	80.7	
Wt. Coefficient	6.0	9.6	11.9	14.4	13.6	

* Total shrimp production in five months per unit area

The food for tanks 5 to 7 was 52% frozen small shrimp and 48% neck clam meat with shell.

The numbers and concentrations of young shrimp introduced were as follows:

Tank 5 - 15,000 (150/m^2) Total weight 1,125 kg

Tank 6 - 28,000 (280/m^2) Total weight 2,100 kg

Tank 7 - 15,000 (150/m^2) Total weight 1,125 kg

Tanks 5 and 6 each had a double bottom structure over 1/10 of the total bottom area of the tank. Tank 7 had no double bottom structure. One tenth of the total area consisted of a sand floor. The thickness of the sand floor was about 10 cm in all three tanks. Water temperature is indicated in Table VIII. Oxygen concentration (cc. per liter) is shown in Table IX.

Tank 5 produced almost a 100% survival rate, (98.9%), even though a fairly high density of 150/m^2 of young shrimp was used. Tank 7 produced an 80.7% survival rate. In Tank 6 the density of the young shrimp per unit area was 280/m^2, and the survival rate was only 53.6%, considerably inferior to those of Tanks 5 and 7. It appears that a good survival rate and a normal growth of shrimp can be obtained with a density of 150/m^2 of young shrimp.

TABLE VIII

Average water temperature (°C) for each ten-day period during density experiments

Month	Period	Temperature (°C)		Month	Period	Temperature (°C)	
		a.m.	p.m.			a.m.	p.m.
June	11-20	20.7	21.8	September	1-10	28.3	29.6
	21-30	24.7	28.0		11-20	23.6	25.1
					21-30	20.4	21.8
July	1-10	22.2	23.5				
	11-20	22.6	26.6	October	1-10	19.5	21.4
	21-30	28.4	30.6		11-20	19.1	20.3
					21-30	15.2	17.1
August	1-10	29.1	30.6				
	11-20	28.8	30.2	November	1-10	13.2	13.8
	21-30	27.7	29.2				

Table IX

Average oxygen concentration (cc./1) for each ten-day period during density experiment

	June	July			August			September			October			November
Tank (5)	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st
05.00 h	4.90	4.34	3.69	2.88	2.85	4.15	3.71	3.44	4.55	4.53	4.19	3.90	4.34	4.54
15.00 h	7.22	7.48	7.60	6.29	6.15	8.06	6.42	5.84	7.44	7.32	7.78	7.38	7.55	7.69
21.00 h	5.44	5.61	5.04	3.27	3.22	4.24	3.48	3.37	4.37	4.44	4.10	3.87	4.42	4.79

	June	July			August			September			October			November
Tank (6)	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st
05.00 h	4.07	4.63	3.94	3.93	3.81	4.44	4.71	3.52	4.09	4.92	4.91	4.63	5.35	4.56
15.00 h	6.95	7.52	7.22	6.25	5.64	5.29	7.08	5.91	6.16	5.84	6.90	7.07	7.78	7.26
21.00 h	4.55	4.91	4.21	3.08	3.17	3.94	4.10	2.72	3.41	4.22	4.20	4.42	4.93	4.57

	June	July			August			September			October			November
Tank (7)	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st
05.00 h	4.12	4.07	3.36	2.34	2.50	2.84	2.87	2.49	3.87	4.69	4.20	3.56	3.47	4.48
15.00 h	6.58	6.85	6.94	6.09	5.71	7.14	6.10	5.59	6.31	6.86	7.39	6.88	5.91	6.09
21.00 h	5.90	5.29	4.43	3.02	2.86	3.92	2.61	2.47	3.44	4.14	3.77	3.53	3.95	4.74

5 PROSPECT OF PENAEID SHRIMP CULTURE

In Japan the price of shrimp is very high. That is why the Kuruma shrimp (P. japonicus) culture pays on a commercial basis even in waters of relatively low temperature like the Seto Inland Sea. In winter, head-on shrimp costs about $8 per kg. If the shrimp price fell to half the present price, the shrimp culture enterprises would become bankrupt. We should not expect the method of Karuma shrimp culture now practised in Japan to be commercially profitable in other temperate countries.

Generally speaking, penaeid shrimp are abundant in the coastal waters of tropical and subtropical zones. The best places for shrimp culture in future should be sought in tropical and subtropical regions. Vast and boundless marshes, swamps or jungles in the tropics or subtropics will be made available for suitable shrimp farms. These areas are at present not utilized for any production purpose and are thought useless, but they are the best places for penaeid shrimp culture. Abundant solar energy and warm water are really gifts of heaven. It is not impossible to harvest shrimp twice a year if the water temperature in winter does not fall under 20°C. Fortunately, the mass production technique of Kuruma shrimp fry has been developed. I believe this technique is applicable not only to the production of Kuruma shrimp but also to that of penaeid shrimp in general.

The feeding of shrimp remains a problem, but it will be solved before long. The technique of propogating natural food organisms for shrimp in the tropics and subtropics by fertilisation will develop in the future.

In this way, the cultivation of the vast and boundless marshes, swamps or jungles in the tropics or subtropics as penaeid shrimp culture farms will greatly contribute toward the increased supply of animal protein to the human race.

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CRECIMIENTO, MIGRACION Y ECOLOGIA DEL CAMARON COMERCIAL *Artemesia longinaris* BATE

por

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Extracto

En el transcurso de los años 1965 y 1966 se analizaron 22.300 ejemplares de esta especie de ambos sexos. El trabajo continúa en 1967. El material proviene de las capturas de la pesca comercial de Mar del Plata. Además se realizaron numerosas observaciones de animales vivos en acuarios para estudiar el crecimiento, comportamiento y desarrollo de larvas y postlarvas obtenidas de muestras de plancton.

Las estimaciones del crecimiento mensual y anual se realizaron empleando la ecuación de v.Bertanlanffy ajustada mediante la transformación de Ford-Walford. Se analizó la proporción de sexos, relación largo total/largo caparazón y relación largo/peso. Los camarones entraron en 1966 en la fase de explotación pesquera a los 40-67 mm de largo total, con seis a siete meses de vida; a los 17 meses de vida y 11 en la región de pesca, las hembras alcanzan de 109 a 136 mm y los machos de 70 a 91 de lt.

De acuerdo con el ritmo de crecimiento del camarón en las costas de Mar del Plata, se produce una migración a fines de cada año, bien evidente, aguas afuera. Los camarones que migran son hembras y machos maduros sexualmente, los cuales posiblemente se concentren para la reproducción en una región aun desconocida, en aguas algo más profundas.

E/45

GROWTH, MIGRATION AND ECOLOGY OF THE COMMERCIAL SHRIMP Artemesia longinaris BATE

Abstract

A total of 22,300 specimens of this species, of both sexes, were studied during 1965 and 1966, and the work is continuing in 1967. The material was obtained from commercial catches at Mar del Plata. Many observations were also made of live shrimp in aquariums to study the growth, behaviour and development of larvae and postlarvae obtained from plankton samples.

The estimates of monthly and annual growth were made using von Bertanlanffy's equation adjusted by the Ford-Walford transformation. The sex ratio and the overall length/carapace length and length/weight ratios were analysed. In 1966 the shrimp came of exploitable age in their sixth or seventh month at overall lengths of 40 to 67 mm; at 17 months and during the 11 shrimping months, females grow to overall lengths of 109 to 136 mm and males to 70 to 91 mm.

As part of the growth cycle of shrimp along the Mar del Plata coast, a very apparent seaward migration takes place at the end of every year. The migrating shrimp are sexually mature males and females, which possibly gather for reproduction purposes in an area as yet unknown in somewhat deeper waters.

CROISSANCE, MIGRATION ET ECOLOGIE DE LA CREVETTE COMMERCIALE Artemesia longinaris BATE

Résumé

En 1965 et 1966, 22,300 individus des deux sexes de cette espèce ont été examinés. Les échantillons provenaient des captures commerciales faites à Mar del Plata. En outre, de nombreuses observations ont porté sur des animaux vivants élevés en aquarium pour étudier la croissance, le comportement et le développement de spécimens aux stades larvaire et postlarvaire obtenus avec des échantillons de planoton.

Pour déterminer la croissance mensuelle et annuelle, on a utilisé l'équation de v. Bertanlanffy après ajustement (transformation de Ford-Walford). On a étudie la répartition par sexe, le rapport longueur totale/longueur de la carapace et le rapport longueur/poids. Les crevettes sont parvenues en 1966 à la phase d'exploitation halieutique avec une longueur totale de 40 à 67 mm, à l'âge de 6 à 7 mois; à 17 mois, et à 11 mois dans la zone de pêche, les femelles atteignent 109 à 136 mm et les mâles 70 à 91 mm de longueur totale.

Le cycle de croissance de la crevette, sur les côtes de Mar del Plata, comporte à la fin de chaque année une migration très nette vers d'autres eaux. Les crevettes qui migrent sont des femelles et des mâles arrivés à maturite sexuelle, qui se concentrent peut-être pour se reproduire dans une région non encore connue où les eaux sont un peu plus profondes.

1 INTRODUCCION

El estudio biológico pesquero del camarón Artemesia longinaris Bate, 1888 (Penaeidae), se realiza en el Instituto de Biología Marina de Mar del Plata, con la ayuda financiera del Consejo Nacional de Investigaciones Científicas y Técnicas de la Argentina (Subsidios 1410 a y b). Los objetivos principales de este trabajo son conocer el ritmo de migración, crecimiento, ciclo sexual, comportamiento de adultos y larvas y la explotación comercial de la especie de la región de Mar del Plata. Estos primeros resultados presentados tratan algunos de los temas enumerados, dejándose para otras contribuciones el resto.

El camarón se captura en las aguas costeras de la Argentina, en todo el litoral de la provincia de Buenos Aires hasta el norte de la Patagonia, a 43°S. Su distribución hacia el norte del continente americano llega a Río de Janeiro, a 23°S (Boschi, 1964; Mistakidis y Neiva, 1964). En las aguas costeras de la ciudad de Mar del Plata se pesca comercialmente esta especie durante casi todo el año, en particular de agosto a noviembre. En los meses de diciembre a julio se capturan ejemplares más pequeños y de menor interés para el mercado de la alimentación. A pesar de ser un peneido de talla mediana, es apreciado para el consumo humano por la excelente calidad de su carne. Además tiene valor en todo el litoral bonaerense como carnada para la pesca deportiva, y es por esta razón que en muchas ocasiones supera el precio de las especies de mayor talla.

2 MATERIAL Y METODO

2.1 Muestreo

El estudio del camarón de la región de pesca de Mar del Plata se inició en el año 1965, continuándose durante 1966 y 1967. La fuente principal de material se obtuvo de las capturas comerciales desembarcadas en el puerto pesquero local, provenientes en su mayor parte de una misma embarcación e idéntica región de pesca. También se lograron muestras directamente de las capturas sobre las lanchas en las continuas salidas del personal del Instituto de Biología Marina a la región de pesca comercial. El muestreo consistió en el análisis de lotes de un número variable de ejemplares obtenidos cada semana en el primer año y quincenalmente los siguientes. Algunos lotes muy viciados fueron despreciados y otros no incluidos en los gráficos. Además se capturaron ejemplares vivos para estudiar el crecimiento y comportamiento en acuario. Las muestras de plancton con redes de Hensen permitieron obtener estadios larvales (protozoea y mysis) y postlarvas para cultivarlas en cautividad.

2.2 Medidas y observaciones

Se han empleado tres medidas principales: 1) largo total, desde la punta del rostro a la punta del telson, con la precisión del milímetro y tomado con compás; 2) largo del caparazón, que corresponde a la distancia entre el seno orbitario y la parte posterior del caparazón del cefalopereion, con la precisión de 0,1 mm y tomado con calibre; 3) peso total del ejemplar en gramos. Además en las hembras se determinó el estado de madurez sexual y de cada muestra se guardaron aproximadamente de 15 a 20 ejemplares para observar el contenido estomacal y las gónadas al microscopio, especialmente la estructura de los ovocitos.

Tanto el largo total como el largo del caparazón dieron buenos resultados para los fines de este estudio. Es evidente que si se trabaja sobre una embarcación o con material en formalina es preferible escoger el largo del caparazón. Cuando el examen de las muestras se realiza en el laboratorio y material fresco, el largo total es una medida conveniente. En este caso se desechan los ejemplares con rostro roto, que en nuestro caso no llegaron a un número importante. El largo total da una real idea del tamaño del animal y es preferido por los pescadores. Conviene establecer índices de conversión para cada medida, lo cual facilita las comparaciones.

2.3 Agrupación

El material estudiado fue agrupado en intervalos de 3 mm para las clases de largo total y cada un mm para los largos de caparazón. La distribución de frecuencias en por ciento se observa en las Figuras 1, 2 y 3[1] y ambas medidas han resultado útiles y mantienen la misma modalidad de distribución.

3 PROPORCION DE SEXOS

Del total de 22.300 ejemplares estudiados durante 1965 y 1966 se halló la siguiente distribución sexual:

1965				1966			
♀♀	♂♂	total	χ^2	♀♀	♂♂	total	χ^2
7.792 69,92%	3.352 30,07%	11.144 100,00%	15,88 $P<0{,}01$	7.365 66,03%	3.789 33,96%	11.154 100,00%	10,36 $P<0{,}01$

La prueba de χ^2 dio diferencia altamente significativa entre sexos para la relación esperada de 1:1, lo cual demuestra que esta desviación se debe a causas distintas del azar. Es evidente que los factores que más inciden en la relación entre machos y hembras en las muestras analizadas en la región de Mar del Plata es la doble selección motivada por la red de captura y la del pescador sobre el barco. Las capturas del camarón que se desembarcan en el puerto de Mar del Plata están constituidas en la mayor parte por hembras por ser los animales más grandes y de mayor interés comercial. Debido a la acentuada diferencia de crecimiento entre machos y hembras, éstas llegan a una talla mayor que aquéllos en menor tiempo. Esto se comprueba al comparar los resultados con los lotes estudiados sobre la embarcación de pesca, sin la selección del pescador, aproximándose el número de hembras y machos y en algunos casos los machos superan a las hembras. No se descarta la posibilidad de que en algunos meses del año la relación entre sexos puede ser afectada por el ciclo migratorio de la especie, como pareció surgir del muestreo obtenido en 1967 en el sur de la provincia de Buenos Aires en una campaña de pesca exploratoria (Boschi y Scelzo, 1967).

4 RELACION LARGO TOTAL/LARGO DEL CAPARAZON

El punteado obtenido de la comparación entre el largo total y el largo del caparazón en ambos sexos da una franja aproximadamente recta (Figs. 4, 5 y 6) pero, al calcular la curva mediante una regresión exponencial se observa que la relación entre ambos atributos es levemente curvilínea (Fig. 6). No obstante se puede considerar para el camarón, con fines prácticos, esta relación recta dentro de las tallas estudiadas. En otros peneidos la diferencia es de mayor significancia (Kutkuhn, 1966).

El factor de conversión promedio para machos y hembras entre ambas medidas es de 4,7 veces el caparazón en el largo total, en ejemplares de 30 a 130 mm de lt. La tendencia en ambos sexos es que con el aumento de la talla el caparazón está más veces en el largo total. Estos valores oscilan entre 4,46 y 4,95.

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[1] En el trabajo se incluyen a efectos de ilustrar sólo 3 histogramas.

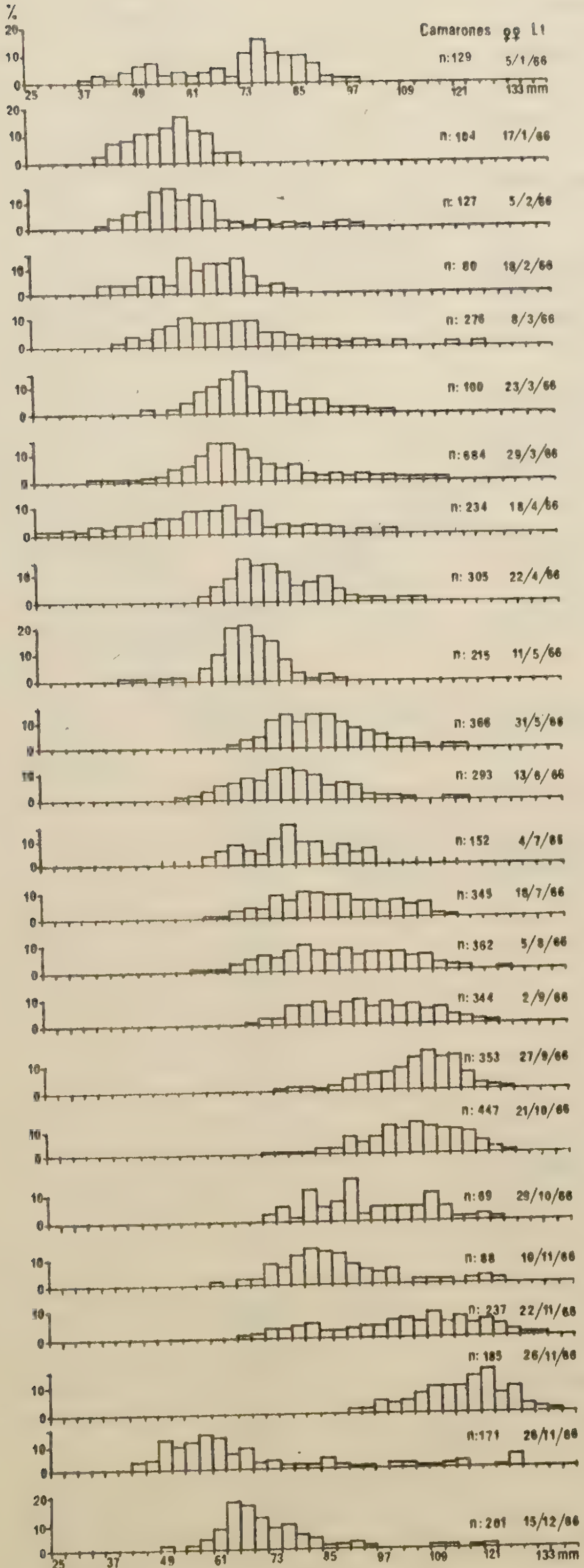


Fig. 1 Distribución de las muestras, en por ciento, del largo total de los camarones hembras del año 1966. La agrupación se efectuó con intervalos de 3 mm.

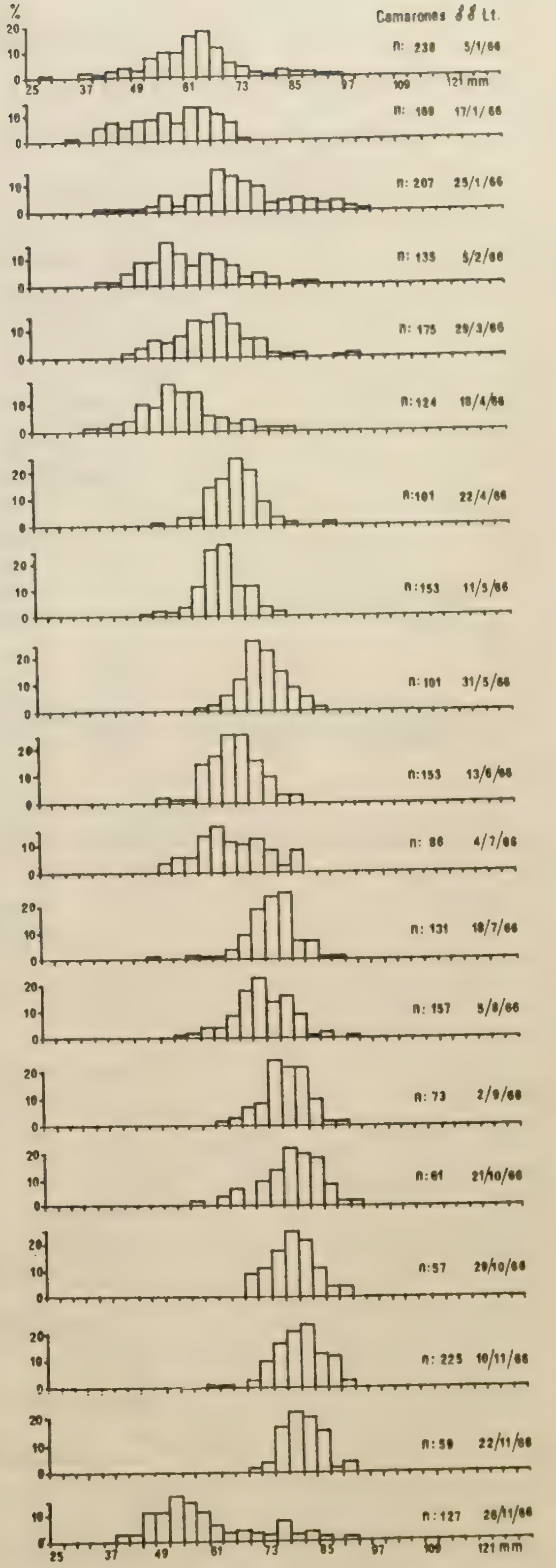


Fig. 2 Distribución de las muestras, en por ciento, del largo total de los camarones machos del año 1966. La agrupación se efectuó con intervalos de 3 mm.

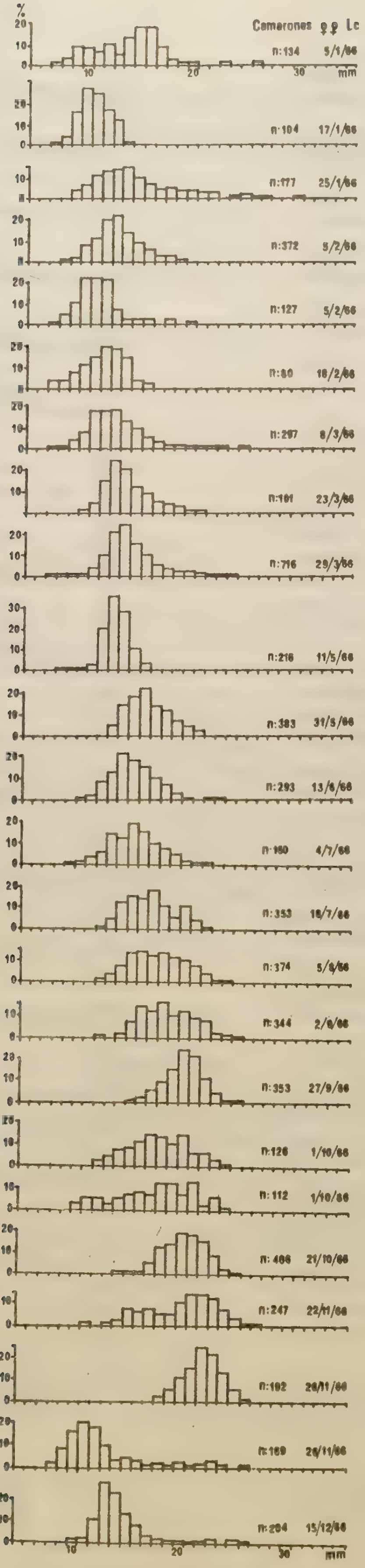


Fig. 3 Distribución de las muestras, en por ciento, del largo de caparazón de los camarones hembras del año 1966. La agrupación se efectuó con intervalos de 1 mm.

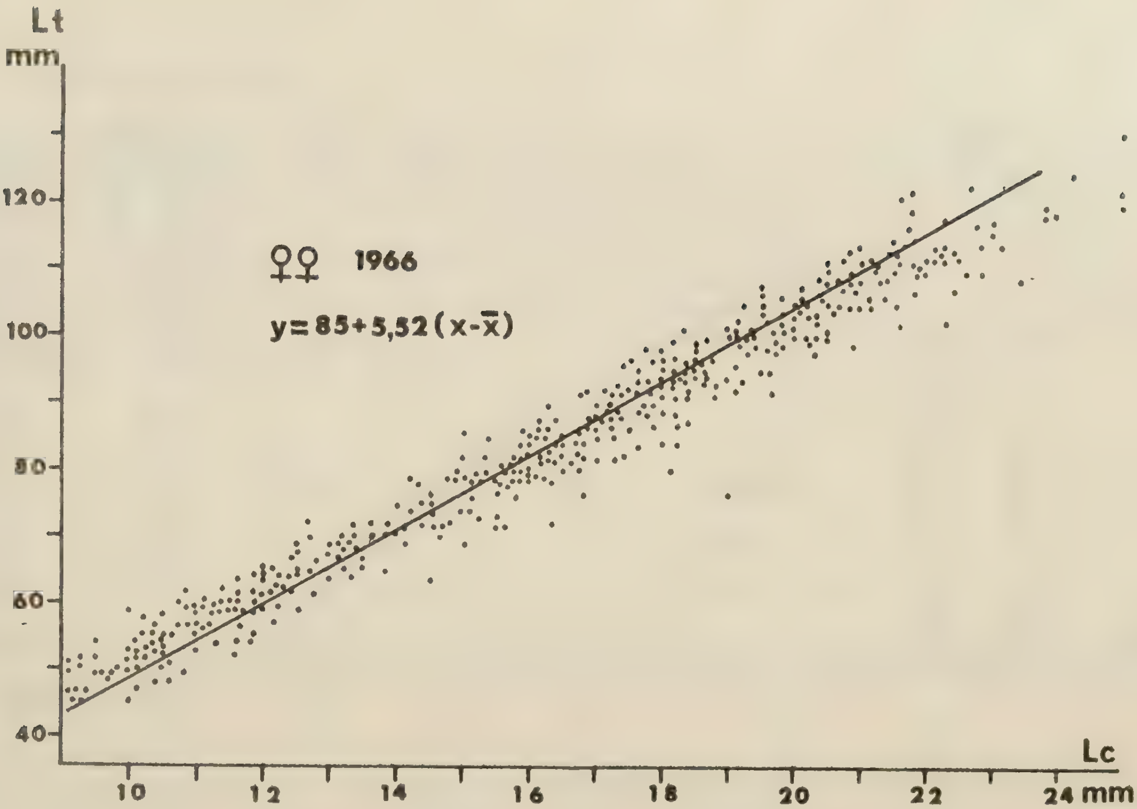


Fig. 4 Regresión entre el largo total y el largo caparazón para hembras de 1966.

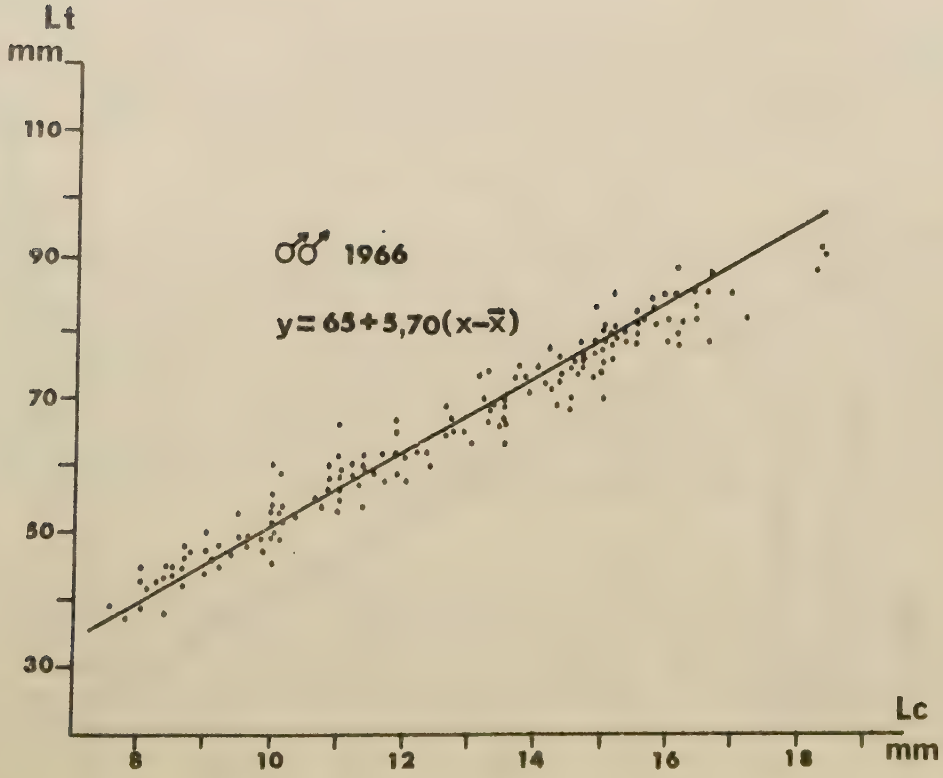


Fig. 5 Regresión entre el largo total y el largo del caparazón para machos de 1966.

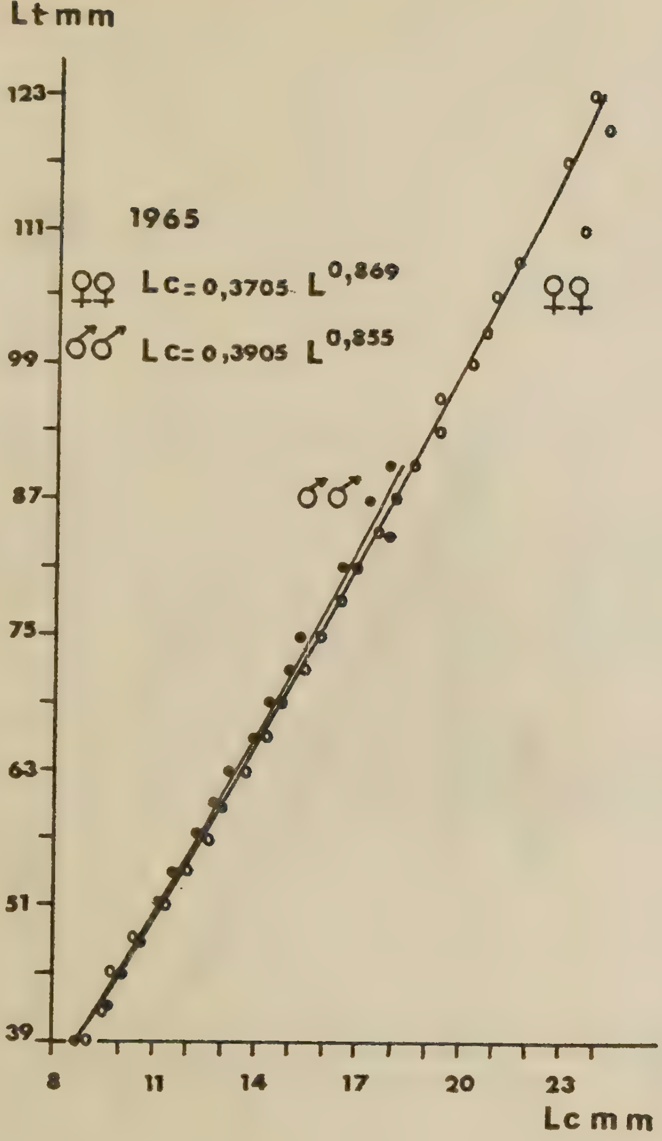


Fig. 6 Regresión curvilínea entre el largo del caparazón y largo total para ambos sexos de 1965.

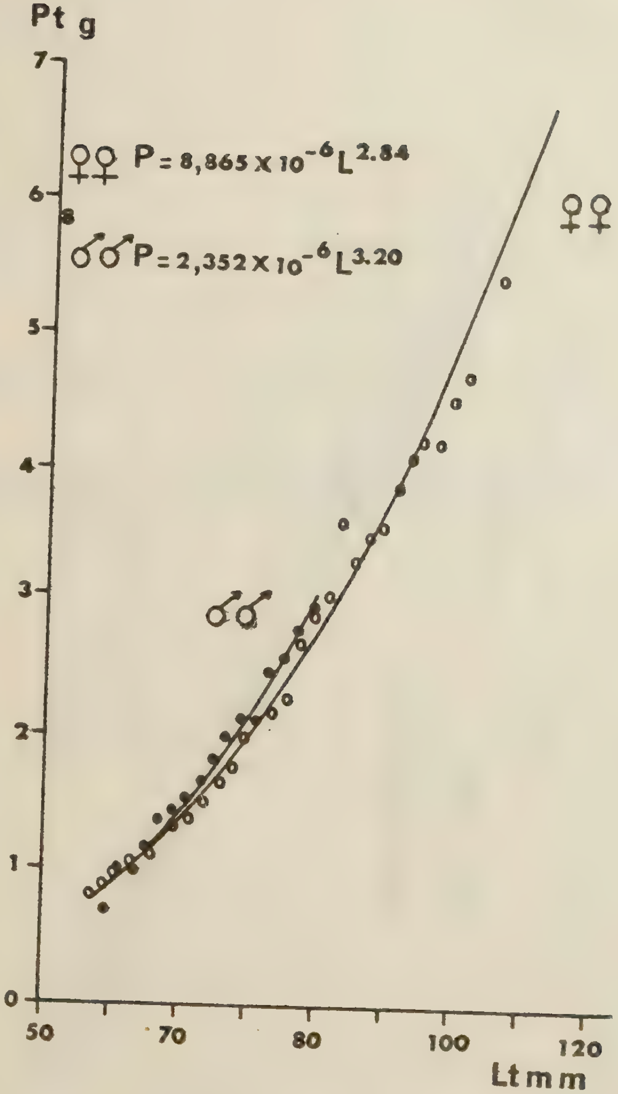


Fig. 7 Relación largo total/peso total para camarones de 1965. Hembras N=295 y Machos N=70.

5 RELACION LARGO/PESO

Se ha realizado el cálculo de la regresión curvilínea del peso total como función del largo del caparazón y del largo total, separados por sexo. Las curvas logradas demuestran una diferencia entre machos y hembras (Figs. 7 y 8). Los valores gráficos y matemáticos de las curvas para el largo total de las hembras, destacan una gran divergencia en las tallas mayores, en relación con los machos. Ello en parte se debe a la presencia del rostro que en las hembras es más largo que en los machos. Se han observado algunas variaciones entre los lotes de distintas épocas del año, pero las diferencias son escasas. Los exponentes más elevados de las ecuaciones calculadas corresponden a los machos, según se puede apreciar:

Año 1965

Machos	Hembras
Lt, n: 3,20	Lt, n: 2,84
Lc, n: 3,18	Lc, n: 2,85

Estos resultados concuerdan con las investigaciones de otros autores (Kutkuhn, 1966).

6 CRECIMIENTO

El crecimiento se estudió mediante frecuencias del largo de individuos de una misma población de camarón en el transcurso de los años 1965 y 1966. En razón de obtenerse las muestras periódicamente, los ejemplares han sido agrupados por sexos y representados en histogramas, tanto para el largo total como para el largo del caparazón (Figs. 1, 2 y 3). Ello permitió seguir mensualmente el desplazamiento de las clases modales a través de todo el año y estimar el crecimiento mensual y anual. Sobre la base de observaciones en acuario y crecimiento de postlarvas, se ha podido establecer que el camarón entra por primera vez en la fase de explotación en la región de Mar del Plata aproximadamente a los seis meses de vida. Partiendo de esa edad y seleccionando los valores modales de las curvas de frecuencias se puede determinar el crecimiento en largo real y teórico de los camarones de la población explotada. Una de las fórmulas que se adaptan convenientemente para este último fin es la propuesta por L.v.Bertalanffy (Beverton y Holt, 1957; Ricker, 1958), cuya expresión es la siguiente:

$$L = L\infty \left[1-e^{-K(t-t_0)}\right]$$

Para la obtención de los parámetros de la referida ecuación se utilizó el método de Ford-Walford. Este da una línea recta punteando el largo a la edad t en la abscisa contra el largo a la edad t + 1 en la ordenada, con lo cual se determina la pendiente e^{-K} y se logra la aproximación al largo infinito en la intersección con la línea de 45° y también se determina el coeficiente K de catabolismo (Figs. 9 y 10). El largo infinito puede ser obtenido asimismo algebraicamente. Estos valores deben ser determinados mediante varias aproximaciones hasta lograr el más exacto posible, en razón de las variaciones que pueden introducirse al elegir en las curvas de frecuencias los diferentes largos (modas) correspondientes a distintas edades mensuales (Figs. 1, 2 y 3). En nuestro caso hemos seguido un solo grupo de edad a través del año, determinado por las clases modales más representadas.

Para la estimación del crecimiento se empleó el largo del caparazón y el largo total en el transcurso de los once meses que aproximadamente el camarón es sometido a la explotación pesquera en las aguas costeras de Mar del Plata. La estimación de t_0 se obtuvo mediante la ecuación de Bertalanffy, determinándose este parámetro para cada edad de largo conocido, promediando finalmente estos valores. Los cálculos se realizaron para los años 1965 y 1966 (Figs. 11, 12 y 13).

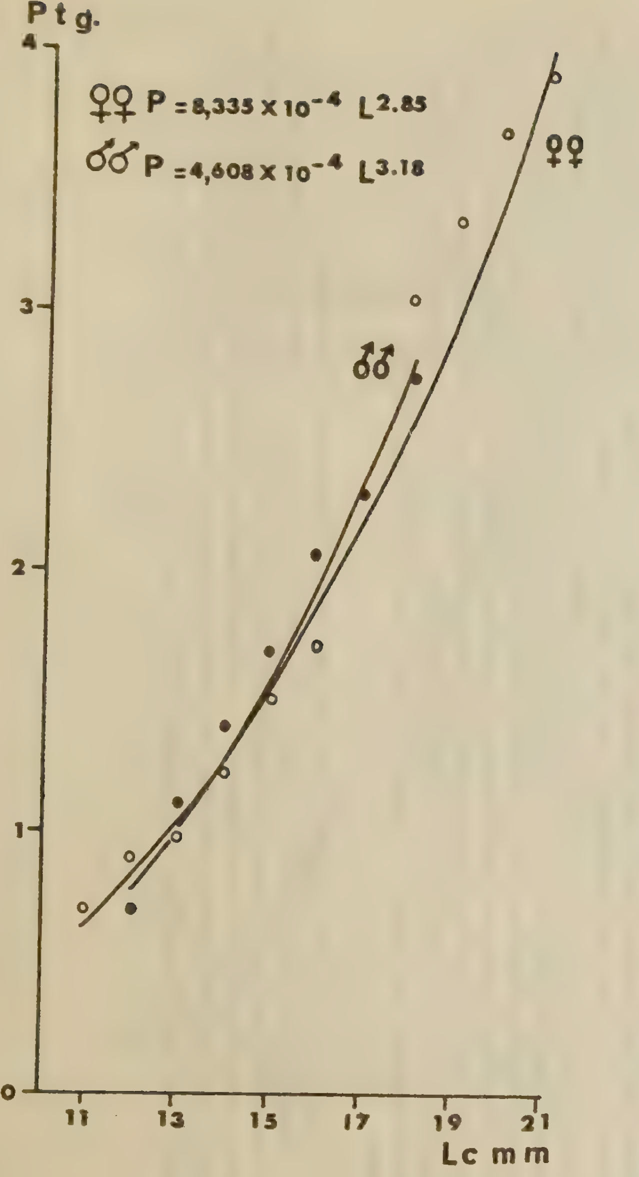


Fig. 8 Relación largo del caparazón/peso total de camarones de 1965. Hembras N=237, Machos N=67.

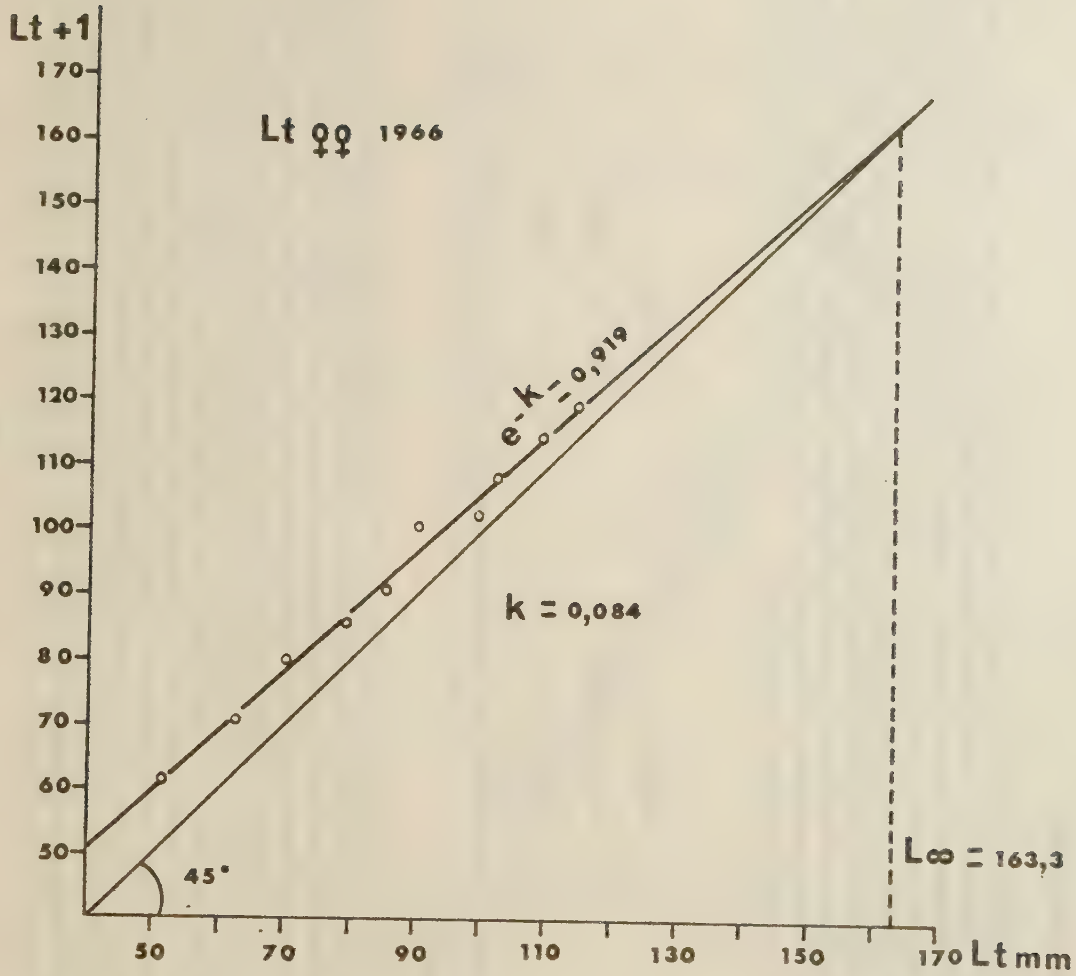


Fig. 9 Gráfico obtenido mediante el procedimiento de Ford-Walford para hallar los parámetros de la ecuación de Bertalanffy. Hembras de 1966.

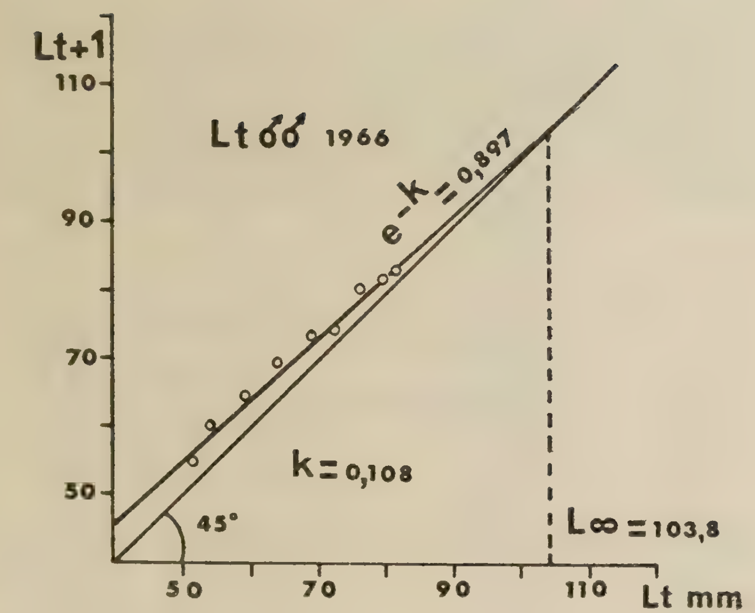
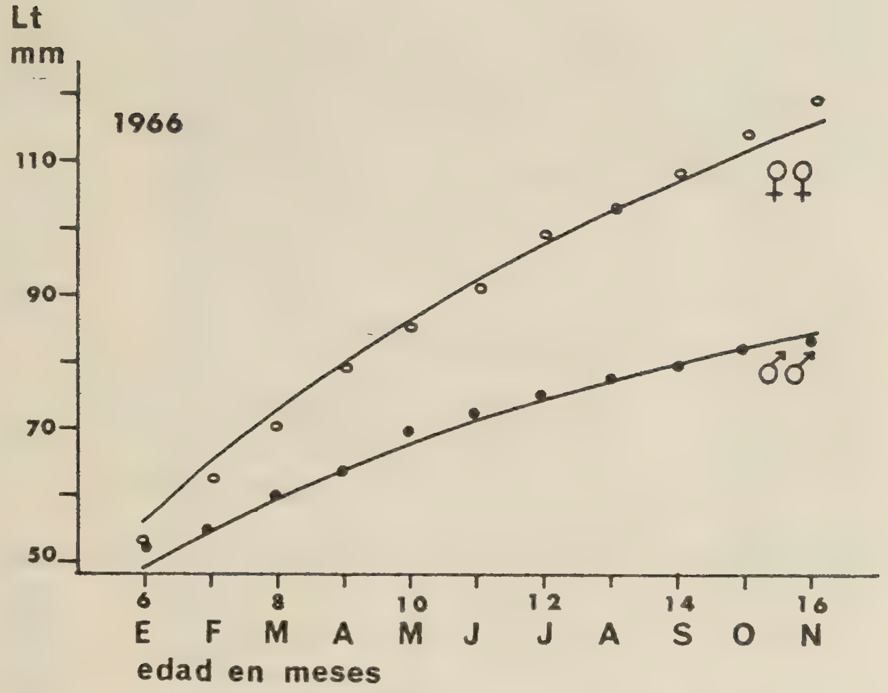


Fig. 10 Gráfico obtenido mediante el procedimiento de Ford-Walford para hallar los parámetros de la ecuación de Bertalanffy. Camarones machos de 1966.

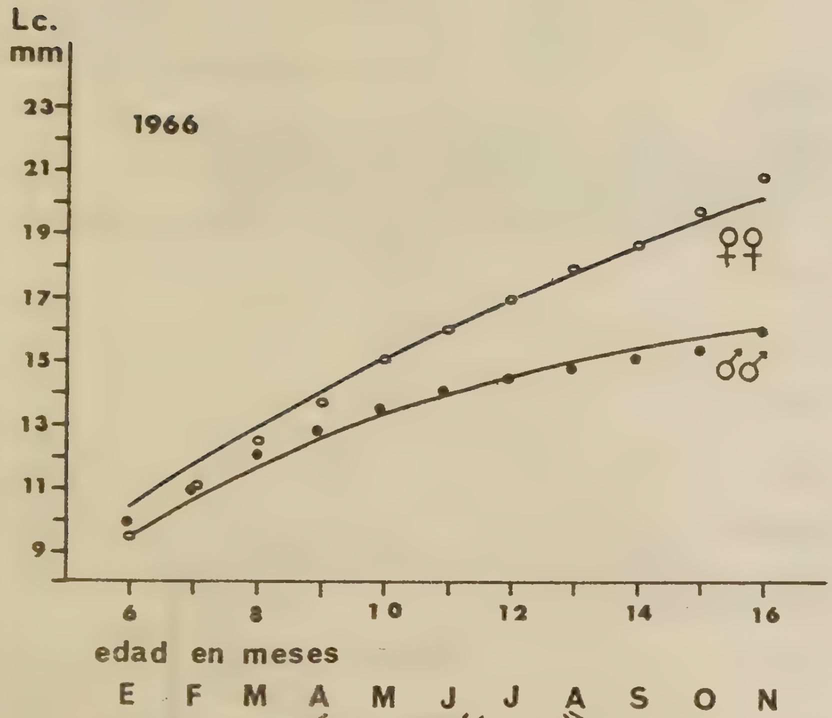


$$Lt = L\infty\left(1-e^{-K(t-to)}\right)$$

hembras $Lt = 163{,}3\left(1-e^{-0{,}084(t-1{,}01)}\right)$

machos $Lt = 103{,}8\left(1-e^{-0{,}108(t-0{,}06)}\right)$

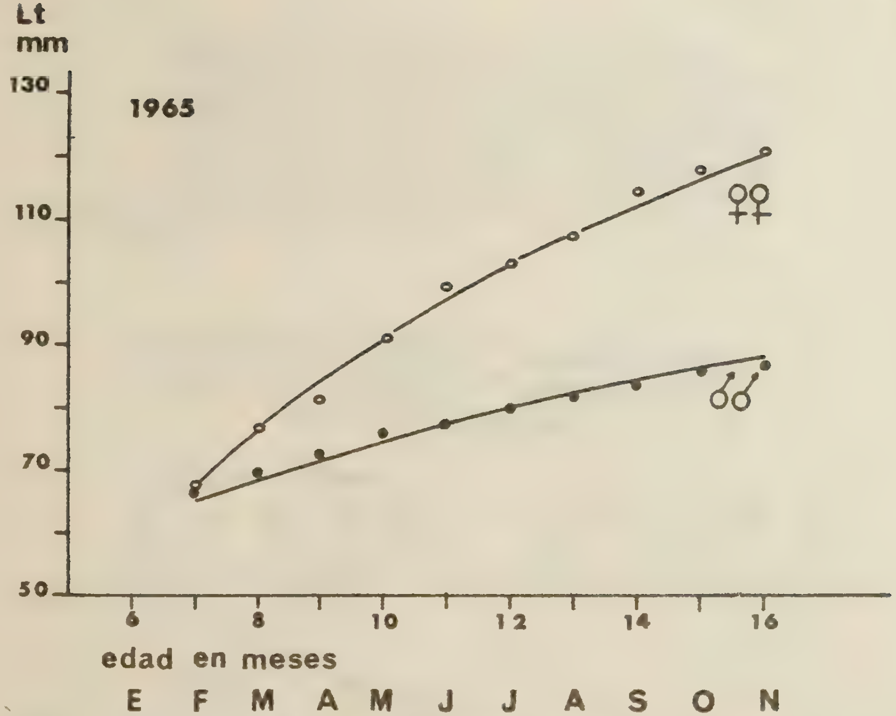
Fig. 11 Curva de crecimiento en largo total para ambos sexos del camarón de la región de Mar de Plata, año 1966. La curva se calculó de acuerdo con la ecuación de Bertalanffy. Los puntos reales corresponden a las clases modales mensuales de las muestras analizadas.



$$♀♀ \quad Lc. = 34,3\left[1-e^{-0,053(t+0,89)}\right]$$

$$♂♂ \quad Lc. = 18,0\left[1-e^{-0,147(t-0,94)}\right]$$

Fig. 12 Curva de crecimiento en largo del caparazón para ambos sexos del camarón de la región de Mar de Plata, año 1966. La curva se calculó de acuerdo con la ecuación de Bertalanffy. Los puntos reales corresponden a las clases modales mensuales de las muestras analizadas.



$$♀♀ \quad Lt. = 149,9 \left[1-e^{-0,112(t-1,56)}\right]$$

$$♂♂ \quad Lt. = 106,74 \left[1-e^{-0,09 (t-3,46)}\right]$$

Fig. 13 Curva de crecimiento en largo total para ambos sexos del camarón de Mar de Plata, año 1965. La curva se calculó de acuerdo con la ecuación de Bertalanffy. Los puntos reales corresponden a las clases modales de las muestras analizadas.

De acuerdo con las curvas las hembras crecen más velozmente que los machos, alcanzando en los once meses que están presentes en la pesca comercial, mucho mayor tamaño que éstos. Para 1966 se estimó el largo total infinito de las hembras en 163,3 mm y para machos en 103,8 mm. Un ejemplar hembra excepcional hallado en nuestro muestreo alcanzó un largo total de 152 mm y de caparazón 29,5 mm. Para 1965 el largo infinito fue estimado para hembras en 149,9 y para machos en 106,7 mm.

Cuando los camarones entran por primera vez en la fase de explotación pesquera en diciembre-enero de cada año en Mar del Plata, oscilan entre 40 a 67, valores éstos que varían de año en año. En 1966 los individuos lograron una moda de 52-53 mm aproximadamente para ambos sexos. Luego, a los 17 meses aproximadamente de vida, en el mes de noviembre y con 11 meses sometidos a la extracción pesquera, llegan aproximadamente a 109-136 mm de largo total, con una moda para el mismo año 1966 de 121 mm. Ello da un aumento de 60-70 mm en el transcurso de los meses de enero a noviembre de ese año. Esto significa un promedio mensual de crecimiento de 9 a 11 mm para camarones de 6 a 7 meses de vida y de 4 a 5 mm para animales de 16 a 17 meses (Fig. 11). Los machos crecen más lentamente y puede observarse que en el mismo año 1966 entraron en explotación con un largo próximo al de las hembras, aumentando de 2 a 4 mm cuando tienen seis meses de vida y de 2 a 3 mm cuando cumplen 16 a 17 meses, alcanzando en esa edad un largo total de 70 a 91 mm con una moda de 79 mm, lo que significa un aumento de unos 30 mm en total. De acuerdo con estos estudios preliminares de la edad y el crecimiento del camarón de Mar del Plata, se puede estimar la vida de esta especie en aproximadamente unos 20 a 22 meses. Es interesante notar que durante todo el año se incorporan nuevos individuos a la fase de reclutamiento con un ritmo de crecimiento variable y que no figuran en los histogramas porque no son capturados por la red o desechados por el pescador.

7 MIGRACION

Estudiando el ritmo de crecimiento del camarón en las costas de Mar del Plata, se deduce que esta especie migra a fines de cada año hacia aguas afuera. En los meses de septiembre, octubre y noviembre se observa una acentuada frecuencia y concentración de las clases de mayor tamaño, que correspondió en 1966 a ejemplares de un largo de 109 a 136, con una moda en noviembre de 121 mm. A partir de ese mes los camarones de las clases mayores se alejan de la región de pesca costera de Mar del Plata (Figs. 1, 2 y 3, mes de diciembre) y quedan en diciembre y enero la gran mayoría de los pequeños que crecen en la región hasta alcanzar el tamaño comercial. Los camarones que migran son hembras y machos maduros, que probablemente se concentran en alguna región aun desconocida en aguas algo más profundas para reproducirse.

8 NUTRICION

Del análisis del alimento de 360 ejemplares de 1965, surge que los componentes principales son los siguientes, según el orden de importancia: restos de crustáceos, algas, tintinidos, detrito y restos irreconocibles. Se hallaron también presentes diatomeas, escamas, copépodos, huevos de peces, espículas de esponjas, foraminíferos, etc. En casi todos los contenidos se halló arena.

9 CONCLUSIONES

La presente investigación ha sido realizada empleando material proveniente en su mayoría de desembarcos de la pesca comercial del camarón (Artemesia longinaris) de la región de Mar del Plata. Estos estudios comenzaron de una manera más organizada en 1965 y se han continuado durante 1966 y 1967. De acuerdo con los resultados obtenidos se puede concluir que el muestreo, a pesar de los vicios mencionados, ha servido convenientemente para el estudio del crecimiento y migración del camarón de Mar del Plata.

Las agrupaciones del largo total y del largo del caparazón sirvieron indistintamente para individualizar las clases modales a través de los meses del año, lo cual permitió estimar el crecimiento real y teórico y evidenciar el ciclo migratorio de la especie.

Todos estos resultados sobre el crecimiento y la longevidad del camarón deben ser considerados preliminares, los que serán complementados con las futuras investigaciones.

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E/46

OBSERVATIONS ON THE SHRIMP FISHERIES OF THE CENTRAL AND SOUTHERN COAST OF BRAZIL

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Abstract

This work presents some observations on the shrimp fishery of the central and southern regions of Brazil. It is based on the data collected at Santos, one of the principal fishing ports of this region. The species which have most attracted the attention of the fishing industry, and which offer the best prospects, are the pink shrimp (*Penaeus aztecus*[1] and *Penaeus brasiliensis*), the sea bob shrimp (*Xiphopenaeus kroyeri*) and the white shrimp (*Penaeus schmitti*). A preliminary analysis of the data indicates that shrimp stocks are under-explored and that the motorized fleet is badly equipped and inefficient. Much of the fishery is from local non-motorized boats and the evaluation of production is difficult.

The deficiencies of the fishing ports, and of methods of unloading, storage and carriage of shrimps are reviewed. The small number of industries utilizing shrimp products could be expanded. Exploration of new fishing grounds in central and southern Brazil should have first priority.

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[1] According to Perez Farfante (*Proc.biol.Soc.Wash.*, 80:83-100, 1967) *Penaeus aztecus* "Form C", should be considered as a separate species: *Penaeus paulensis*.

OBSERVATIONS SUR LES PECHERIES DE CREVETTES DU LITTORAL BRESILIEN CENTRAL ET MERIDIONAL

Résumé

La communication présente quelques observations sur les pêcheries de crevettes du littoral central et méridional du Brésil, fondées sur les données recueillies à Santos, l'un des principaux ports de pêche de la région. Les espèces auxquelles s'intéresse le plus l'industrie des pêches et qui paraissent les plus intéressantes sont *Penaeus aztecus* et *P. brasiliensis*, *Xiphopenaeus kroyeri* et *P. schmitti*. Sur la base d'un premier examen des données, il semble que les stocks de crevettes soient sous-exploités et que les bateaux à moteur soient mal équipés et aient un rendement insuffisant. Le gros de la pêche s'effectue à partir de bateaux locaux non motorisés, et l'évaluation de la production est difficile.

La communication passe en revue les insuffisances des ports de pêche et les défauts des méthodes de débarquement, d'entreposage et de transport des crevettes. Les industries utilisant les crevettes sont peu nombreuses, pourraient être développées. La priorité devrait être accordée à la prospection de nouveaux fonds de pêche dans les eaux du Brésil central et méridional.

OBSERVACIONES SOBRE LAS PESQUERIAS DE CAMARONES DE LAS COSTAS CENTRALES Y MERIDIONALES DEL BRASIL

Extracto

Este trabajo presenta algunas observaciones sobre las pesquerías de camarones de las regiones centrales y meridionales del Brasil. Se basa en los datos recogidos en Santos, uno de los principales puertos pesqueros de esta región. Las especies que han atraido más la atención de la industria pesquera, y que ofrecen las mejores perspectivas, son el camarón rosado (*Penaeus aztecus* y *P. brasiliensis*), el camarón de siete barbas (*Xiphopenaeus kroyeri*) y el camarón blanco (*P. schmitti*). Un análisis preliminar de los datos indica que las poblaciones de camarones se hallan poco exploradas y que la flota motorizada está mal equipada y es poco eficaz. Gran parte de la pesca se realiza con embarcaciones locales no motorizadas y es difícil la evaluación de la producción.

Se examina la deficiencia de los puertos pesqueros, y de los métodos de descarga, almacenamiento y transporte. El pequeño número de industrias que emplean productos camarones podría ampliarse. Debe tener máxima prioridad la exploración de nuevos caladeros en el Brasil central y meridional.

1. INTRODUCTION

Approximately 9 percent of the fish landings made at Santos consist of shrimp. As the value of the shrimp fishery is about 35 percent of the total, it is considered as one of the most valuable fishery resources of the central and southern regions of Brazil. Actually, the exploitation of these crustaceans appears to be a stimulating factor for the promotion and industrialization of the fishery. Already it has attracted private capital for its further exploitation.

There are four commercial categories of shrimp exploited by the shrimping fleet: the "camarão rosa" - Brazilian pink shrimp - (Penaeus aztecus and P. brasiliensis), the "camarão sete barbas" - sea bob - (Xiphopeneus kroyeri), the "camarão legitimo" - white shrimp - (Penaeus schmitti), and the "camarão sete barbas de Santana" (Hymenopenaeus muelleri). The last species is fished almost exclusively by the Guanabara fleet, on the north coast of the State of Rio de Janeiro. The other species are fished all along the Brazilian coast by the artesanal fishery, but the highest landings are taken in the central and southern regions by the motorized fleet. On the fishing grounds located in the extreme north of the country the pink shrimp are being exploited by foreign fishing fleets.

The medium price per kg (heads-on) of these various species fluctuates a little during the year. In Santos, during March 1967, the medium price per kg was:

	N Cr[1]	US$
Pink shrimp	5.00	1.85
Sea bob shrimp	1.50	0.56
White shrimp	4.00	1.48

It has been observed that the fleet tends to operate over the traditional fishing areas, situated near the principal market centers of São Paulo and Rio de Janeiro, where satisfactory catches can be obtained. Thus numerous other areas of greater potential production remain unexplored.

Observations have shown that shrimp exploration on the Brazilian coast can and should be urgently intensified, not only to contribute protein supply to our population, but also for export. Shrimp may become a source of significant importance to the economy of Brazil, comparable with or exceeding the lobster production of the northeast.

2 PINK SHRIMP (CAMARÃO ROSA)

2.1 General considerations

On the Brazilian coast exist two species of shrimp that are captured together, thus establishing a commercial category known as the "pink" shrimp. On the central and southern coasts P. aztecus is the species prevailing in the catches, but occasionally P. brasiliensis predominates.

Observations have shown that the biology of these species is similar to that observed for other similar species in the North Atlantic. Spawning takes place in oceanic regions in depths of 50 m. Examination of samples obtained has shown females with ovaries ready to spawn and with characteristic spent ovaries. This fact, allied to the presence of penaeid larvae in plankton samples, confirms that the present fishing grounds are situated in the areas of spawning.

---

[1] New Cruzeiros

The larvae reach the coastal brackish waters, where they spend part of their lives. After some time they gradually move away from the estuarine waters appearing after some months with the adult stocks, some 25 to 30 mi (46 to 56 km) off the coast. Observations suggest that the spawning period is quite long, mostly in the second half of the year. This leads to concentrations of juveniles in estuarine waters in the first half of the following year.

2.2 The fishery

There are two types of fishery: an artesanal fishery, which concentrates principally on young shrimps (about 120 to 150 shrimps per kg, heads-on), when these are growing in estuarine waters; and a motorized fishery, responsible for capturing adult shrimp (about 15 to 25 shrimps per kg, heads-on) at a distance of approximately 30 mi (56 km) off the coast, at a depth of about 50 m.

The artesanal fishery employs a variety of gear, and is being practised all along the Brazilian coastline. In the center and south coast the largest catches of young shrimps take place in the Lagôa dos Patos, Rio Grande do Sul, and Laguna, Santa Catarina, during the summer and autumn. In the bays of São Francisco, Paranaguá, Cananéia, Santos and Guanabara, the fishing season is approximately the same. The motorized fishery extends from the State of Espírito Santo to the south of the State of Santa Catarina (Fig. 1).

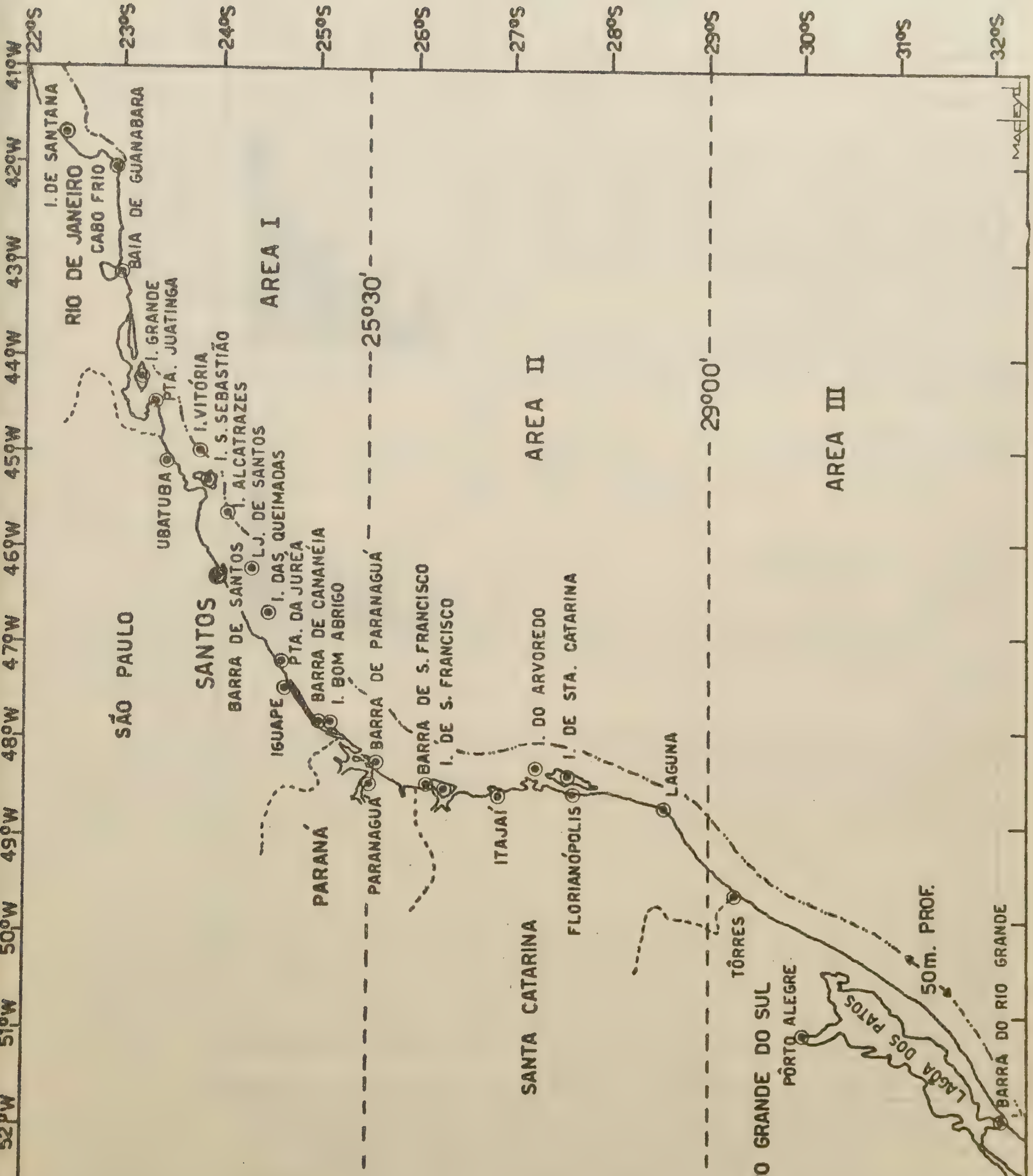
The fleet consists principally of boats measuring about 17 m in length, but some are of only 12 m and others of 20 m or more. These concentrate on fishing adult pink shrimp. The boats are constructed of wood, with small cabins on the stern, and are generally poorly equipped. The side trawl system is used, and the nets are of synthetic fiber. The crew consists of 9 to 10 men. Fishing takes place during the night and occasionally during the day. During the night each boat executes 2 to 3 hauls, each of 4 to 5 h duration. The Santos fishing fleet consists of about 85 fishing boats of 16 to 20 m in length, 7 of nearly 12 m and 8 of more than 20 m. During certain periods of the year, the sardine boats (purse-seine) and the pair trawlers adapt their gear for the pink shrimp fishery.

The Guanabara fleet is similar but there are probably rather fewer boats. It operates in the same areas as the Santos fleet, but its landing data are unfortunately not controlled. In the States of Santa Catarina and Parana, thanks to Governmental action, a shrimping fleet has commenced to develop and production statistics are being recorded.

In addition to the pink shrimp, the boats obtain small quantities of fish, of small commercial value, the most common being the salmonete or trilha (Pseudomulloides carmineus). Frequently the catches contain small numbers of the shrimp Sicyonia typica and sometimes some lobsters, known as "sapatas" (Scyllarides brasiliensis) as well as octopus (Octopus sp.) and squids (Loligo spp.). When the boats fish some miles from the traditional grounds, they capture specimens of Lagostinho (Nephrops rubellus). Over certain fishing grounds, such as, for example, near the Lage de Santos and the Queimada islands (Fig. 1), the scallop (Pectinidae) is abundant.

2.3 Statistical data

For a better analysis of the data, the central and southern regions have been separated into three areas (Fig. 1), taking into consideration the known positions of greater concentrations of pink shrimp, the fleet's radius of action and the localization of the principal ports of landing. Area I lies between 22° and 25°30' S; area II between 25°30' and 29° S; and area III beyond 29° S. Data on the motorized fleet fishing are available only from areas I and II. No information is available of pink shrimp catches from area III. Fig. 2 is based on landings made at Santos from areas I and II, and compares production, fishing effort (number of hauls) and production per haul (kg/haul) for the two areas. Quarterly data for 1964 to 1966 and annual data for


22°S
23°S
24°S
25°S
26°S
27°S
28°S
29°S
30°S
31°S
32°S
41°W
42°W
43°W
44°W
45°W
46°W
47°W
48°W
49°W
50°W
51°W
52°W
53°W
I. DE SANTANA
RIO DE JANEIRO
CABO FRIO
BAIA DE GUANABARA
AREA I
I. GRANDE
PTA. JUATINGA
I. VITÓRIA
I. S. SEBASTIÃO
I. ALCATRAZES
L.J. DE SANTOS
I. DAS QUEIMADAS
I. DAS JURÉA
PTA. DA JURÉA
BARRA DE CANANÉIA
I. BOM ABRIGO
UBATUBA
SÃO PAULO
SANTOS
BARRA DE SANTOS
IGUAPE
25°30'
BARRA DE PARANAGUÁ
PARANÁ
PARANAGUÁ
BARRA DE S. FRANCISCO
I. DE S. FRANCISCO
AREA II
I. DO ARVOREDO
I. DE STA. CATARINA
ITAJAÍ
FLORIANÓPOLIS
SANTA CATARINA
LAGUNA
29°00'
TÔRRES
AREA III
RIO GRANDE DO SUL
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LAGOA DOS PATOS
50m. PROF.
BARRA DO RIO GRANDE
Madeyd

Fig. 1 Areas and localities of the shrimp fishery in the central and southern regions of Brazil.

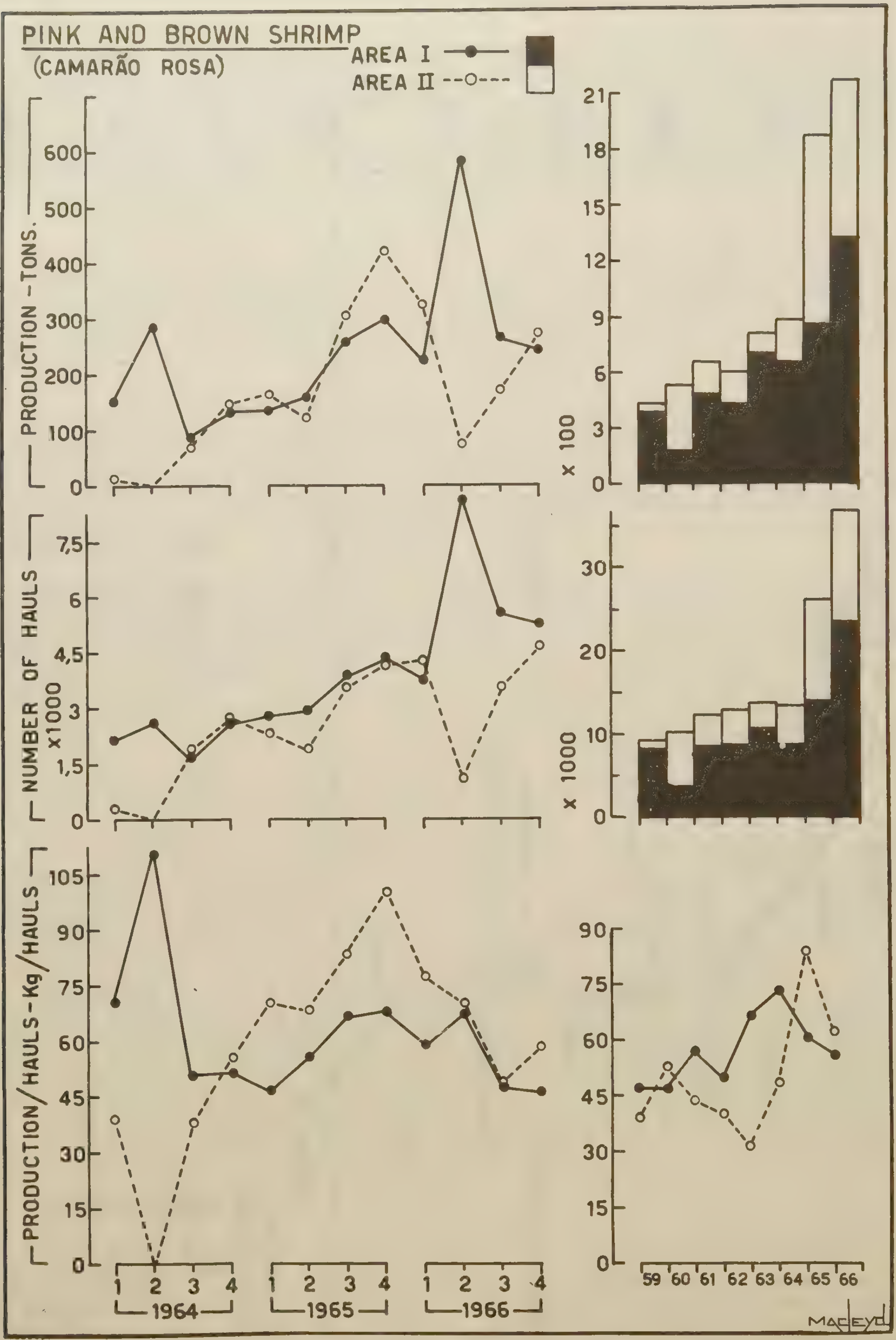

Fig. 2 Statistical data from the port of Santos referring to the pink shrimp fishery from areas I and II. Quarterly data for 1964-66 and annual for 1959-66, related to landings (tons), number of hauls, and production per haul (kg/haul).

1959 to 1966 are given. On the basis of these the following observations can be made:

(i) Production has increased with fishing effort. In 1965 production was nearly triple that of 1964, while the fishing effort nearly doubled. In 1966, production increased by 16 percent in relation to 1965, while the effort increased by 41 percent; this represents a drop of 18 percent in the yield of the average haul.

(ii) The fishing effort (number of hauls) has been higher in area I than in area II, due to the proximity of area I to the principal consumer centers and landing ports of Santos (São Paulo) and Rio de Janeiro (Guanabara). The annual average per haul in area II was inferior to that in area I until 1964, which may have been due to inadequate exploration of area II. In 1965 and 1966, however, the average annual yield per haul in area I was 61 and 57 kg, while in area II it was 85 and 63 kg, or 40 percent and 10 percent more respectively. This indicates that the ecological conditions of the areas II and III (still virgin for an oceanic fishery) are potentially more important than area I.

(iii)The average annual yield per haul was stable until 1963, then it improved a little with the introduction of nets made of synthetic fibres. In 1964 and 1965 yields remained at about the same level. In 1966 there was a drop of 18 percent.

(iv) The tendency of the fleet has been to concentrate in certain fishing areas, and an increase in effort in area I may result in a drop in effort in area II, and vice versa. The analyses of data suggest that variation in abundance relative to the fishing areas is not connected with the fishing effort.

3 SEA BOB (CAMARÃO SETE BARBAS)

3.1 General considerations

The "sea bob" (X. kroyeri), which is an abundant species on the Brazilian coast, becomes rare south of the State of Santa Catarina, and also in offshore grounds. Of all the shrimp landed in Santos it is the one which brings the lowest prices per kg. This factor and its abundance make it of significant importance as a source of protein to populations of the coastal regions.

All the sea bob landed in Santos come from the São Paulo coastline. It is found in shallow coastal waters, but, in contrast to pink and white shrimps, it does not enter brackish waters during its life cycle. It occurs in areas where the bottom is of mud or mud with sand. Biological observations show that this species has a prolonged period of spawning, particularly during summer and autumn. Their growth is rapid and their life lasts about 18 mo.

3.2 The fishery

Although this species is fairly abundant in other areas along the São Paulo coastline, it is fished in a relatively small area, within a radius of 20 mi from the mouth of the Santos Bay (Fig. 1), and in less than 30 m depth. One of the reasons that the fleet remains in this traditional fishing area is its location near the great consumer market of the State of São Paulo. This area does not yield extremely profitable catches, but the sea bob does not preserve well, even in ice, and the fishermen risk losing all their catch through deterioration if they fish on more distant grounds.

At the moment, approximately 80 boats fish sea bob regularly. The majority, known as "baleeiras", are less than 12 m in length; they are equipped with small motors and operate otter trawls. Some operate as pair-trawlers or "parelhinhas". The tendency in the last few years has been the transformation of the "parelhinhas" into "baleeiras", possibly for economic reasons. Larger boats that pursue other types of fishing, and stay away from port for many days at a time, discard any sea bob that they catch. Occasionally such boats land this shrimp when it is caught on the last day of the trip.

The crews of these boats vary from three men on the "baleeiras" to ten men on the "parelhinhas". The nets used by the "baleeiras" are smaller than those used by the "parelhinhas" and the mesh in the cod end is approximately 12 mm between knots. Generally on the "baleeiras" the nets are hauled directly by hand, while on the "parelhinhas" they use a manual winch.

The catches of these fishing boats vary in composition, but the principal species is usually the sea bob, with individual weights between 1 and 10 g (heads-on), together with some white shrimp (P. schmitti). At certain times of the year young pink shrimps (P. aztecus and P. brasiliensis) are also captured, and fishes of commercial value, such as croakers (Macrodon ancylodon and Micropogon furnieri), stone croaker (Cynoscion petranus), various species of shark and other fishes of small size and value.

Fishing is carried out from "sun to sun", that is the boats begin their operation at sun rise and terminate just before sun set of the same day. In general three hauls are made per fishing day, with an average duration of 2.5 h. The "parelhinhas" make fewer but longer hauls.

The fishing timetable appears to be correlated to the behaviour of the species. Some observations made at different points of the São Paulo coast showed that the yield decreased considerably during the night, becoming less at dusk, and improved at sun rise, suggesting that this species is more active during the day.

3.3 Statistical data

The quarterly (1964 to 1966) and annual data of the Santos Bay fishery based on catches made by "baleeiras" and "parelhinhas" are shown in Fig. 3.

The small pair-trawlers ("parelhinhas") have the tendency to abandon the sea bob fishery and proceed to areas more distant from Santos, seeking better quality fish. Others continue to fish the sea bob, using otter trawls like the "baleeiras". The analysis of this fishery indicates that the production, which increased with an increase in the effort, dropped abruptly in 1965 (by 56 percent) while the fishing effort (number of hauls) dropped by only 18 percent. The fall in the yield per haul was of the order of 46 percent. In 1966, the number of hauls rose by 10 percent in relation to 1965, and production also increased by 10 percent.

Studies already made suggest that the productivity of this area is limited, and that the fleet is already catching the maximum possible yield of sea bob.

4 WHITE SHRIMP (CAMARÃO LEGITIMO)

4.1 General considerations

The "white shrimp" (P. schmitti), whose biological characteristics are similar to the white shrimp of the North Atlantic, occurs along the Brazilian coasts as far south as the State of Santa Catarina (Laguna). It is not as abundant as the same species in the North Atlantic. In the center and south coast of Brazil, it is fished in small quantities. It is a littoral species, occurring in areas with the same characteristics demanded by sea bob, tending to disappear, like the sea bob, away from the coast. Observations made at Santos show that this species spawns in depths of 25 m. The larvae reach the inshore waters where they find appropriate conditions for growth. After some months the young shrimps move off shore, mixing with the adult stock. It has been observed that spawning begins in August and lasts until January, providing concentrations of young shrimps in growth areas by the end and beginning of the year. In the Santos area the young shrimp begin to join the fishable adult stocks in the middle of the year.

4.2 The fishery

The white shrimp is taken with the sea bob, and some pair-trawlers of medium size (15 to 20 m) concentrate on the white shrimp and discard the sea bob because of its poor

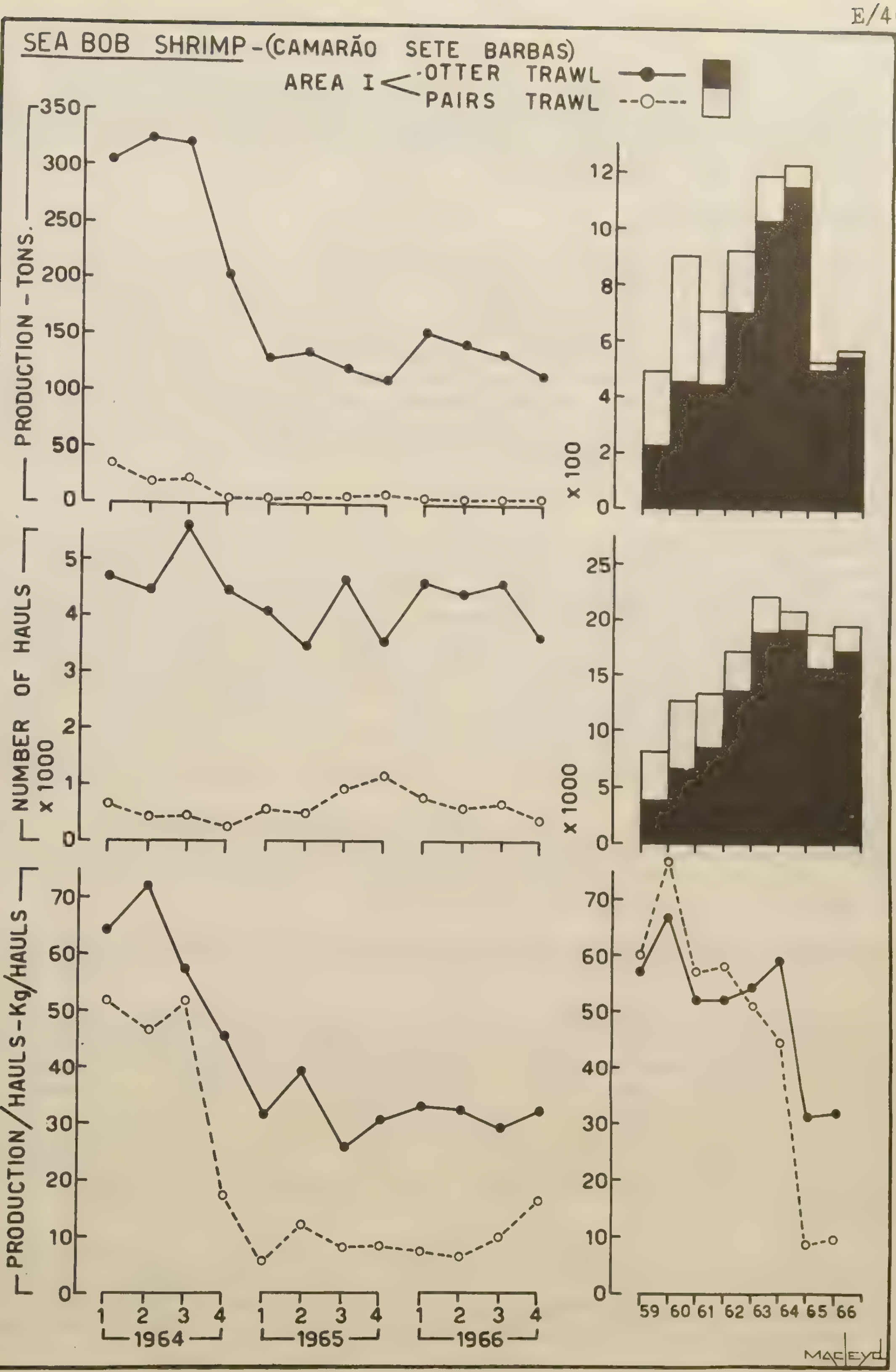

Fig. 3 Statistical data from the port of Santos referring to the sea bob shrimp fishery in area I (Santos Bay). Quarterly data for 1964-66 and annual for 1959-66, related to landings (tons), number of hauls, and production per haul (kg/haul), for otter-trawlers and small pair-trawlers.

keeping qualities. During part of its life cycle, the white shrimp is taken in inshore waters, together with the pink shrimp, by the artesanal fishery, but the quantities obtained cannot be estimated. On these occasions both the white and pink shrimp are sold in Santos as live bait for fish.

4.3 Statistical data

The relevant data on production and fishing effort of the small otter trawlers (baleeiras), small pair-trawlers (parelhinhas) and medium pair-trawlers that operate in areas I and II (Fig. 1) are shown in Fig. 4. The data are insufficient for a conclusive analysis. It has been observed that the biggest catches have been obtained by the medium pair-trawlers. In area I, production fluctuates considerably. It can be seen that in 1964 to 1966 the best catches were made in the second half of each year. This coincides with the spawning period, when the species moves to offshore grounds. This species appears to be taken in large quantities by the artesanal fishery on the coasts of Paraná and Santa Catarina and also in northern Brazil.

5 DISCUSSION

This investigation shows that the shrimp stocks of Brazilian waters have not been explored adequately. The partial statistical coverage of the shrimp fishery makes it impossible to give complete figures of total production, even of the central and southern areas of Brazil. Actually, the artesanal fishery produces more than the motorized fishery. Although the motorized fishery has a great tendency to expand, it is antiquated, badly equipped and utilizes techniques which do not permit full exploitation of the stocks. The annual shrimp production in the central and southern regions has been calculated to be between 20,000 and 25,000 tons. It is believed that 30 to 35 percent of this total is produced by the motorized fishery and 65 to 70 percent by the artesanal fishery. Production could increase further if fishing techniques improved and if more processing plants were set up to take advantage of the extra production.

The marine fishery in Brazil passes through decisive critical periods. The interest which has stimulated it recently can easily make it progress further in a very short time. The new code of Fisheries elaborated by governmental organizations and advised by FAO will be the basis for such progress.

On the basis of the above analysis it is permissible to comment on the following points:

(i) Fishing fleet: It is expected that by the end of 1967 the fleet engaged on pink shrimp should double. The national ship-owners have shown great interest in obtaining modern and well-equipped boats, similar to the ones used at present in the Gulf of Mexico, and some of these are already operating in Brazilian waters. The advent of more boats in the traditional fishing areas will necessitate the exploration of new virgin areas, such as area III (Fig. 1), whose ecological conditions indicate abundant potential shrimp stocks. Governmental organizations must therefore increase exploratory and biological investigations on the principal shrimp species.

(ii) Fishing ports: The actual fishing ports do not meet the minimum technical or sanitary conditions required to support the forseeable development of the fishing industry. In view of the expanding fleet, it is becoming increasingly urgent to construct technically equipped fishing ports, capable of receiving and storing the fishery products.

(iii) Distribution: The uncertain and inadequate means of distribution within the country hinder development of the fishing industry. Exportation provides an alternative outlet for the shrimps and encourages the exploration of new grounds.

(iv) Industries: It has been observed that the present plants situated in the south of the country are insufficient to absorb the production of shrimp caught by

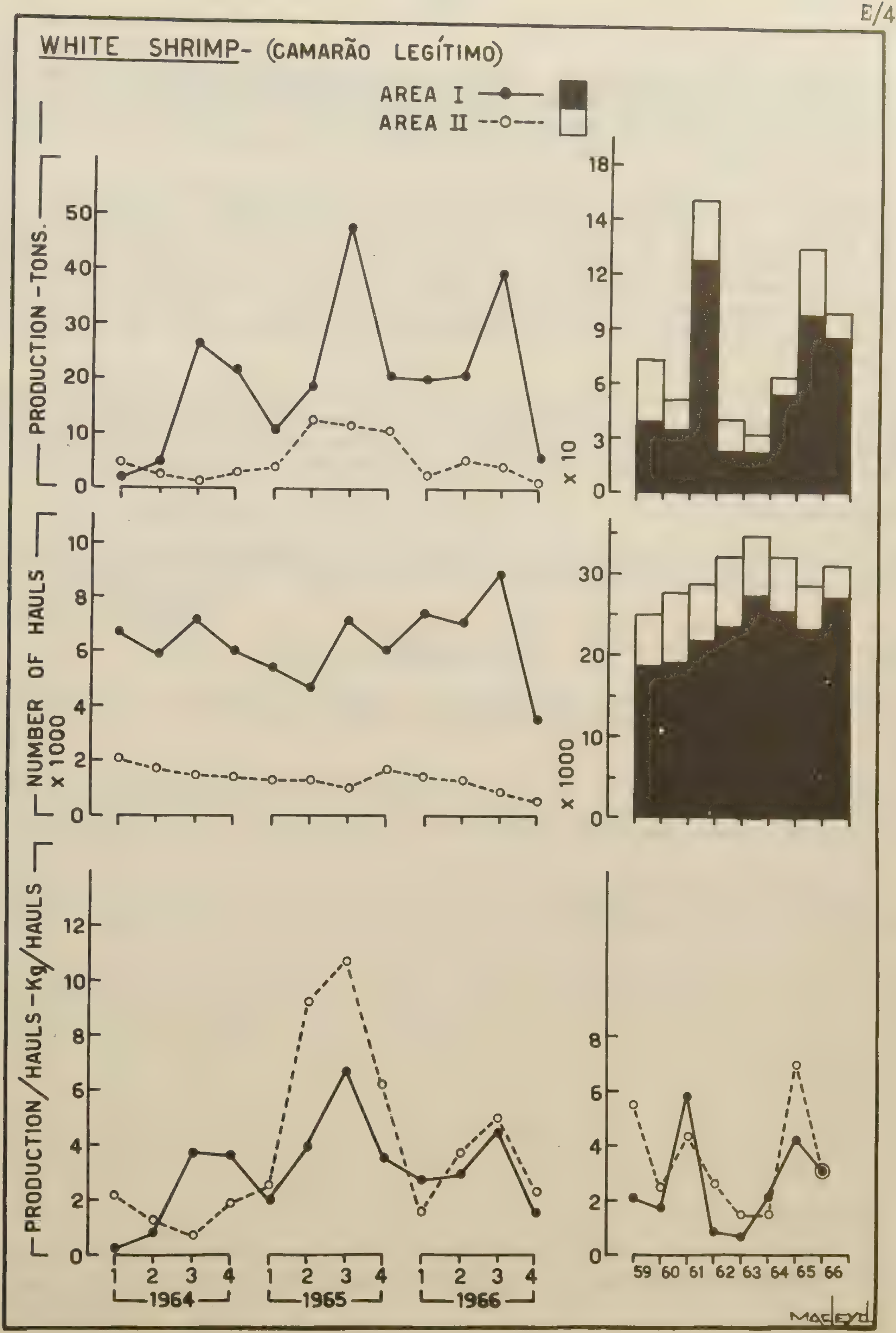

Fig. 4 Statistical data from the port of Santos referring to the white shrimp fishery from areas I and II. Quarterly data for 1964-66 and annual for 1959-66, related to landings (tons), number of hauls, and production per haul (kg/haul).

the artesanal fishery, and this results in considerable wastage. In some productive areas, the Lagôa dos Patos and Laguna, the plants cannot utilize all the production of the young pink shrimp, and the low prices offered by the industry induce the fishermen to dump their production into the water.

The sea bob in Santos Bay is captured within a small area and is fished very intensively. Production per haul has fallen, and the fleet is maintained by raising the market price of shrimp. It is believed that if the Government were to encourage the establishment of industries for the processing of frozen sea bob on the north coast of the State of São Paulo, part of the fleet that now operates in Santos Bay would move to the areas near the new plant. This would relieve the overfishing in Santos Bay and would encourage the exploitation of unexplored regions.

(v) Supply of trained fishermen: Another factor that has prevented the development of the shrimp fleet is the lack of qualified crew for the fishery. A short-term solution to be considered would be the importation of fishery technicians (skippers), until Brazil could organize the training of its own fishermen.

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E/47

LARVAL AND POSTLARVAL PINK SHRIMP *Penaeus duorarum* IN SOUTH FLORIDA *

by

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Abstract

After descriptions of larval and postlarval stages of pink shrimp (*Penaeus duorarum*) were made from reared specimens and from specimens collected from the plankton in the Tortugas area it was possible to determine areas and seasons of spawning.

Spawning occurred in all seasons, but was greatest in spring and summer. Time of spawning was correlated with temperature and was greatest in the latter half of the lunar month. Spawning occurred mostly in the area where commercial fishing is conducted.

Approximately 87×10^{11} first protozoea were produced annually and there was a survival rate of approximately 80.4 percent per day. This produced about 85×10^{8} postlarvae to enter the inshore nursery areas.

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E/47

STADES LARVAIRES ET POSTLARVAIRES DE LA CREVETTE *Penaeus duorarum* DE LA FLORIDE MERIDIONALE

Résumé

Des descriptions de stades larvaires et postlarvaires de crevette *Penaeus duorarum* effectuées sur la base tant de spécimens d'élevage que d'individus provenant du planoton récolté dans la région de l'île de la Tortue, ont permis de déterminer les zones et les époques de reproduction.

La reproduction a lieu toute l'année, mais est plus intense au printemps et en été. Elle dépend de la température, et l'activité maximale est atteinte durant la seconde moitié du mois lunaire. Les frayères coïncident généralement avec la zone exploitée par la pêche commerciale.

La production annuelle de premières protozoés atteint le chiffre approximatif de 87 x 10^{11}, avec un taux de survie d'environ 80,4 pour 100 par jour. En conséquence, environ 85 x 10^8 postlarves pénètrent dans les zones côtières où elles poursuivent leur développement.

FORMAS LARVALES Y POSTLARVALES DEL CAMARON ROSADO (*Penaeus duorarum*) EN EL SUR DE FLORIDA

Extracto

Después de las descripciones que se hicieron de las fases larvales y postlarvales del camarón rosado (*P. duorarum*) a partir de ejemplares criados y de ejemplares recogidos en el plancton de la zona de los cayos de las Tortugas, fue posible determinar las áreas y temporadas del desove.

El desove se verificó en todas las temporadas, pero fue máximo en primavera y verano. El período del desove se relacionó con la temperatura, siendo mayor en la segunda mitad del mes lunar. El desove tuvo lugar sobre todo en la zona en donde se realiza la pesca comercial.

Se produjeron anualmente 87 x 10^{11} primeros protozea, con una tasa de supervivencia de 80,4 por ciento por día, aproximadamente. Esto dió origen a que penetraran en las zonas de cría próximas a la costa de unas 85 x 10^8 postlarva.

1 INTRODUCTION

In 1959, the Institute of Marine Sciences, University of Miami, began a study of the early life history of the pink shrimp Penaeus duorarum Burkenroad. This paper summarizes the work done to date, emphasizes the methods used, and suggests further research.

The purposes of this study were to delimit the spawning area and season of the pink shrimp that support the Tortugas fishery in southern Florida and to describe the distribution of the larval stages on the Tortugas shelf and in Florida Bay (Fig. 1). The study also attempted to estimate total annual production and mortality of larvae.

2 METHODS

2.1 Identification and rearing of larvae

The larval stages of P. duorarum were described by Dobkin (1961) from specimens collected in plankton samples and from specimens reared from eggs spawned in the laboratory. Shrimp were reared in the laboratory from the first naupliar through the first protozoeal stage; older stages were collected in plankton samples. Specimens from plankton samples could be used because P. duorarum is the only member of the genus which has been found in the Tortugas area (Eldred, 1959). No evidence appeared during plankton sampling that larvae of other species of this genus were present. Ewald (1965) subsequently reared all stages in the laboratory and compared them with the published descriptions.

Dobkin (1961) failed to rear Penaeus larvae beyond the first protozoeal stage because the larvae either would not feed or they became entrapped in exuviae or algal food. Ewald (1965) used compartmented clear plastic boxes as described by Costlow and Bookhout (1959) and changed the water daily. Survival of the animals was better in sea water from the Gulf Stream than from Biscayne Bay. Food for protozoeal and early mysis stages was a mixture of Dunaliella tertiolecta and Tetraselmis sp. (flagellates), Phaedoctylum tricornatum (diatom), Chlorella sp. (green alga), and Rhodotorula affinis (yeast). Only young phytoplankton cultures (less than 11 days old) were used to minimize the proportion of less motile (older) stages. Terminal mysis stages and postlarvae were fed nauplii of brine shrimp (Artemia salina).

The optimum temperature for the larvae was 26°C (Ewald, 1965). At 31°C mortality was high, and at 21°C the growth rate was reduced. Protozoeal stages, when feeding began, were the most difficult to maintain. The number of mysis stages varied; more occurred at 21°C than at 25°C.

2.2 Plankton sampling

Plankton samples were collected from the waters of the Tortugas shelf, Florida, from 1959 to 1964. In 1959 to 1962 most samples were collected with a 3/4 m modified 'Discovery' net. A 0.4 m (1 ft) (mouth diameter) 'Turtox' net of No. 6 mesh silk bolting cloth or Nitex No. 216 nylon cloth and a 1/2 m (mouth diameter) 'Arts, Sciences Workshop' net of either Nitex No. 75 or No. 175 nylon cloth also were used. A plankton sled (Frederick M. Beyer, University of Oslo, Oslo, Norway) was used to sample for eggs and nauplii near the bottom.

Discovery-type nets were submerged by using a lead weight attached to the end of the towing wire. The net was attached to the cable 1.5 m above the weight. Paired hauls were made at most stations, and sampling was carried out at three levels: 1.5 m above the bottom, in mid-depth, and 0.5 m below the surface. The levels were sampled either separately or with step-oblique hauls. The depth fished was determined by trigonometric calculations based on the towing angle and the length of cable.

Beginning in February 1960, Tsurumi Precision Instrument Company flow meters were attached in the mouth of the net to estimate the volume of water filtered. Salinity and temperature were recorded for each sample (Munro, Jones and Dimitriou, 1968).

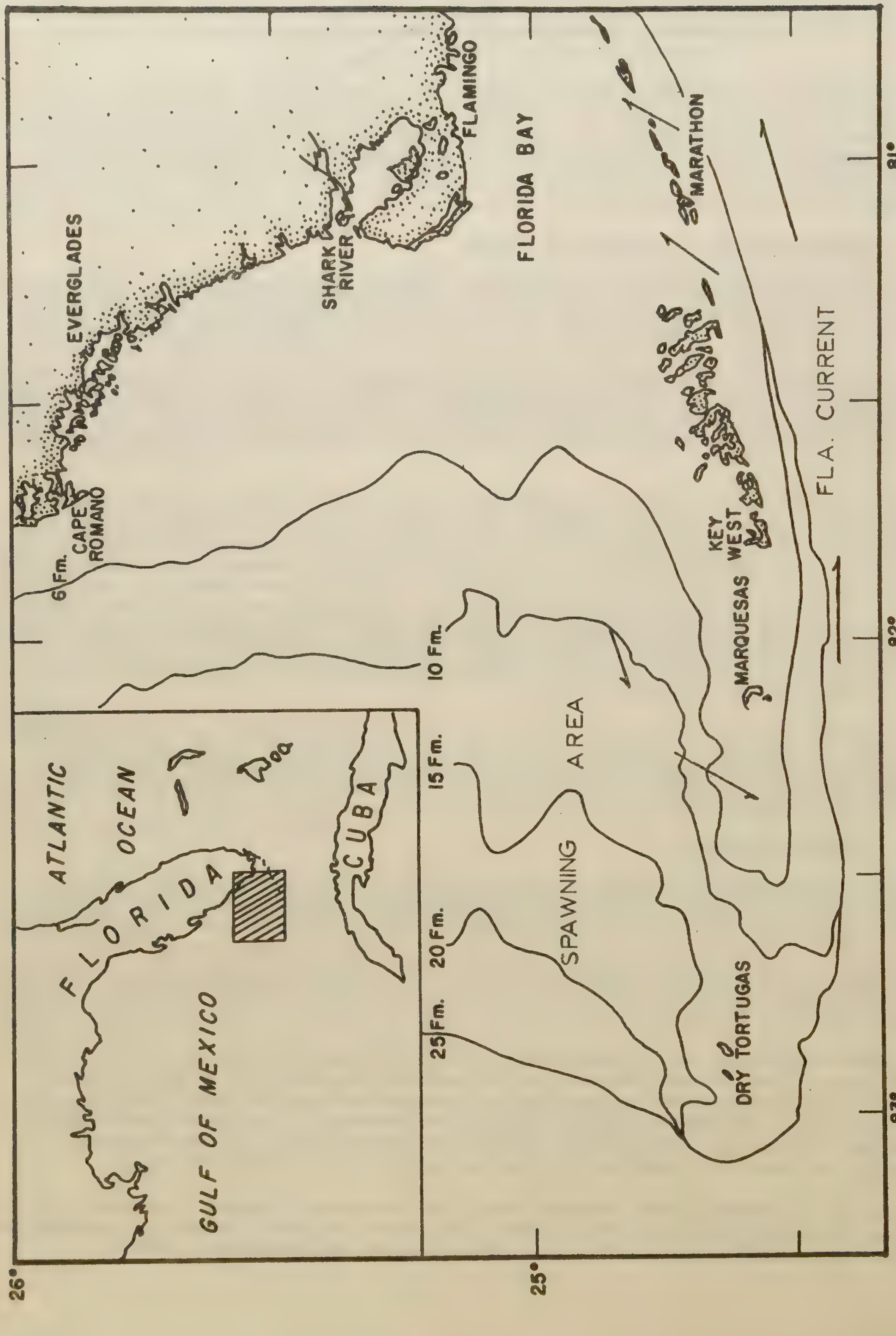
ATLANTIC OCEAN
FLORIDA
CUBA
GULF OF MEXICO
EVERGLADES
CAPE ROMANO
SHARK RIVER
FLAMINGO
FLORIDA BAY
MARATHON
KEY WEST
MARQUESAS
DRY TORTUGAS
SPAWNING AREA
FLA. CURRENT
6 Fm.
10 Fm.
15 Fm.
20 Fm.
25 Fm.
26°
25°
81°
82°
83°

Fig. 1 Spawning and nursery area of Tortugas population of pink shrimp (Penaeus duorarum). Arrows indicate current pattern.

Neither the Discovery-type net nor the Turtox net was completely satisfactory. Comparisons of catches of Discovery and Turtox nets showed that the Discovery nets caught relatively fewer nauplii (35 percent), more protozoea and mysis (133 percent), and more postlarvae (486 percent) than the Turtox nets. In August of 1962, a Gulf-V plankton net (Arnold, 1959) was introduced (Munro, Jones and Dimitriou, 1968). The 0.293 mm mesh opening of this net retained first protozoea (0.35 to 0.44 mm width) and older stages. Nauplii (0.17 to 0.22 mm width) were not retained. The net was equipped with TSK-type flow meters in the mouth. Thirty-minute tows were made in a step-oblique fashion at 10 equally spaced intervals between the bottom and surface.

2.3 Examination of samples

The naupliar, protozoeal, and mysis stages of P. duorarum were separated and counted in the laboratory. Postlarvae were sorted according to the number of rostral spines.

Discovery-net samples were brought to a volume of 400 ml and eight 24-ml aliquot portions sorted. The average percentage difference between total larvae as estimated by a subsample of eight aliquots and the total count was 14.7. Abundance was expressed as the number of shrimp per 700 m^3 water filtered, because this volume was close to the average volume filtered.

The samples from the Gulf-V net were divided by the use of a two-compartment rotating plexiglass cylinder similar to that designed by T.R. Folsom (McEwan, Johnson, and Folsom, 1954). Abundance was calculated as the number of shrimp larvae per m^3 of water filtered and the number of larvae under 10 m^2 of surface.

An amorphous mucilaginous substance which appeared in many of the fresh samples, and which may have resulted from the presence of coelenterates in the plankton, made sorting difficult. This substance was removed from the samples by the following technique, developed by Dr. Eugene Corcoran, Institute of Marine Sciences. The sample of approximately 570 ml was treated with 10 ml of saturated copper ammonium solution and allowed to stand at least 12 h. The resulting precipitate was cleared by the addition of concentrated H_2SO_4 until a pH of 2 was reached. The sample was washed with water in a Buchner funnel until the solution returned to neutral. Suction was applied by a vacuum pump. The sample was then returned to 3 percent buffered formalin for storage.

3 DISTRIBUTION OF LARVAE

The Discovery-net samples showed that the numbers of shrimp at the surface and at mid-depth generally decreased from midnight to midday and increased from midday to the following midnight. Nauplii were seldom taken because they probably inhabit the deepest part of the water column. Youngest protozoea were more common near the bottom, but second and third protozoea and mysis were found to undertake considerable vertical migrations. Postlarvae were more common in the surface tows than in deeper tows.

Results from monthly samples over the entire Tortugas shelf showed that spawning occurred all year and was greatest in the area of commercial fishing. Spawning occurred mostly in the south-central portion of the fishing grounds for most of the year, but shifted to the northwest edge of the area in winter. Shrimp generally did not spawn in water less than 6 fm (11 m) deep.

The numbers of larvae were lowest in winter. An increase in numbers, especially protozoeal and mysis stages, indicated an increase in spawning activity in spring. Several distinct periods of abundance were observed in summer. In fall, numbers of larvae were usually high on the fishing grounds, but numbers of postlarvae were low in the inshore areas.

Jones et al. (1969) found bottom temperature to be of major importance in determining time of spawning. Shrimp spawned, as indicated by the presence of first protozoea, over a temperature range from 19.6 to 30.8°C. Spawning was maximum in the temperature range from 27.0 to 30.8°C. In 1961, the temperature began its seasonal decline in July and August, and the abundance of larvae decreased markedly by early fall.

Salinity changes were small in the area, and the numbers of larvae were not related to salinity.

The methods of Winsor and Clarke (1940) and Silliman (1946) were used to determine the 95 percent confidence limits for the estimates of the number of protozoea present under 10 m^2 of surface area from replicate Gulf-V net tows. These were found to be between 28.8 percent and 347.6 percent of the mean. Similarly, 90 percent confidence limits for Discovery net tows varied between cruises from 11 to 843 percent to 34 and 290 percent of the mean. These limits were wider than those reported by Silliman (1946) and Strasburg (1960), but probably reflected the replicate nature of the tows as compared to the true paired hauls used by Silliman and Strasburg. Data from several 24-h stations revealed no indication of significant changes between catches made in daylight or at night.

Estimates of total production of first protozoea indicated that 60.5 x 10^{11} were produced in 1963 (a poor year); average annual production is estimated at 87.0 x 10^{11} first protozoea (Munro, Jones and Dimitriou, 1968).

Munro, Jones and Dimitriou (1968) corroborated the seasonal cycles and the relation between spawning and bottom temperature noted by Jones et al. (1969) by an additional three years sampling. Spawning appeared to be more intense during the waning moon phases. The increased spawning in the latter half of the lunar month agrees with the work of Korringa (1957), who found that animals that display lunar rythms in spawning often have spawning peaks in the last lunar quarter.

By using data on the duration of each larval stage (Ewald, 1965) and our own catch data, we estimated mortality and survival rates from catch curves. Survival rates varied from 74 percent per day east of Rebecca Channel to 98 percent per day north of Northwest Channel. Survival appeared to be negatively correlated with distance from the Keys or water depth. Munro, Jones and Dimitriou, (1968) obtained an average rate of 80.4 percent survival per day. Jones et al. (1969) calculated the survival rate of the larvae at 85 percent per day in 1961 and 76 percent per day in 1962.

As shown by Tabb, Dubrow and Jones (1962) and work in progress, postlarvae that are about 35 days old enter the Everglades nursery area in the 6 to 7 rostral-spine stage (Ewald, 1965). This information on survival and age implies that about 0.05 percent of the original population survive to enter the nursery grounds. On the basis of the number of first protozoea estimated for 1963 (60.5 x 10^{11}), the survival amounts to 0.14 percent or 85 x 10^8 postlarvae entering the estuary; this would imply that about 6 percent of the postlarvae survived to produce the commercial catch of 5 x 10^8 individuals in 1963.

Both surface currents (Koczy, Rinkel and Niskin, 1960) and bottom currents (Rehrer, Jones and Roessler, 1967) showed a net drift to the southwest. Bottom drift was studied using the U.S. version of the Woodhead sea-bed drifter as described by Lee, Bumpus and Lauzier (1965).

A likely route of larval and postlarval migration is southwest across the grounds, through Rebecca Channel, along the western border of the Florida Current and back into Florida Bay through the channels between the Florida Keys (Munro, Jones and Dimitriou, 1968).

Work in Buttonwood Canal and in the Little Shark River was undertaken to estimate the number of postlarvae entering the Everglades nursery. Paired surface and bottom plankton hauls were made with a 1-m plankton net with nylon mesh (471μ). Samples were taken from a vessel run at a constant engine speed. This procedure produced, as closely as possible, constant filtering behavior of the nets. Preliminary analysis showed catches of postlarvae were greatest in bottom samples made at night and during flood tides, in new and first quarter moon phases. Abundance increased in spring, reached a maximum in July and August, and fell off sharply in late September. Abundance was low during the winter.

4 FUTURE RESEARCH

The present studies show that more information is needed on the duration of the larval instars under natural conditions. Estimates of the production of nauplii and better estimates of the survival rates of the various larval stages are needed. The migration routes need thorough study. Survival and growth of postlarvae, length of time spent in the estuary, and abundance and behavior of postlarvae and juveniles should be studied. At the Institute of Marine Sciences, University of Miami, Dr. D. Hughes is studying some of the behavioral aspects; his results are published in these proceedings. Work by Dr. E. Iversen and B. Yokel at the Institute of Marine Sciences, University of Miami, considers the relation of the abundance of the juvenile stages to catches of adults; some of their results are also presented in these proceedings.

In summary:

(i) We have learned to identify the various larval and postlarval stages.

(ii) We have successfully reared pink shrimp from eggs to postlarvae. (This has resulted in new handling techniques and a diet which should be useful in rearing crustacean larvae in general).

(iii) We have learned the vertical, areal and seasonal distribution of shrimp larvae and postlarvae.

(iv) We have developed a working hypothesis on the migration routes, but this point needs further evaluation.

(v) We have found that temperatures above 27°C encourage highest production of larvae and that spawning occurs mostly during the waning moon phases.

(vi) Estimates show that approximately 87×10^{11} first protozoea are produced annually and that a survival rate of 80.4 percent per day for the larvae and early postlarvae will provide about 85×10^{8} postlarvae for the inshore nursery area.

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ON THE MECHANISMS UNDERLYING TIDE-ASSOCIATED MOVEMENTS OF Penaeus duorarum BURKENROAD [1]

by

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Abstract

Postlarval shrimp move inshore on flood tides while juveniles move offshore on ebb tides. The mechanism whereby this discrimination between the tides is effected appears to be based on the respective responses of postlarvae and juveniles to changes in salinity.

Juveniles are positively rheotactic within a current of water. However, when the salinity of that water is decreased, downstream swimming ensues. This ensures that juveniles will, in nature, resist displacement in an inshore direction by the flood tide but will swim and be displaced in an offshore direction by the ebb tide. There is evidence that the responsiveness of juveniles to decreases in salinity is under rhythmic control.

The postlarvae respond to a decrease in salinity by dropping to the substrate, where they remain inactive and thereby evade displacement by the ebb tide. When the salinity increases (flood tide) they become active in the water column and are displaced inshore.

The apparent dependence of tide-associated movements on changes in salinity points to an explanation for the positive correlations that have been found between the extent of rainfall in the vicinity of "nursery" areas and the commercial catch of the following year.

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OBSERVATIONS SUR LE MECANISME DES MOUVEMENTS DE *Penaeus duorarum* LIES A LA MAREE

Résumé

Les postlarves de crevettes s'approchent du littoral avec la marée montante tandis que les formes juvéniles s'éloignent avec le reflux en direction du large. Il semble que le mécanisme déterminant ces mouvements soit fondé sur la réaction des postlarves et des jeunes aux variations de la salinité de l'eau.

Les jeunes manifestent une rhéotaxie positive. Lorsque la salinité de l'eau diminue, l'animal nage dans le sens du courant. Dans les conditions naturelles, les jeunes luttent contre le flux qui tend à les rapprocher du rivage, mais se mettent à nager et sont emmenés vers le large lors du reflux. Selon certains indices, les réponses des jeunes à l'abaissement du taux de salinité sont soumises à un rythme régulier.

Les postlarves réagissent à une diminution de la salinité en se laissant tomber sur le substrat, où elles restent immobiles, évitant ainsi d'être entraînées par le reflux. Lorsque la salinité croît (flux), elles se remettent en mouvement dans l'eau et sont emportées vers la terre.

Ce rapport apparent entre les mouvements des crevettes liés à la marée et les modifications du taux de salinité fournit un élément d'explication de la corrélation positive qui a été constatée entre l'importance des chutes de pluie au voisinage des zones de développement des jeunes et les prises commerciales de l'année suivante.

SOBRE EL MECANISMO QUE RIGE LOS DESPLAZAMIENTOS DE *Penaeus duorarum* ASOCIADOS CON LAS MAREAS

Extracto

El camarón en su fase postlarval se mueve hacia tierra con la pleamar mientras que las formas juveniles se alejan de la costa con la bajamar. La razón de esta diferencia de desplazamiento en relación con las mareas parece basarse en las respectivas reacciones de las postlarvas y de las formas juveniles a los cambios de la salinidad.

Las formas juveniles son positivamente reotácticas dentro de una corriente de agua. Sin embargo, cuando disminuye la salinidad de dicha agua los ejemplares juveniles nadan aguas abajo. Esto asegura que las formas juveniles resistirán los desplazamientos en dirección hacia la tierra a que los someta la pleamar pero que nadarán y serán desplazados en direción hacia alta mar por la marea menguante. Hay pruebas de que la reacción de los juveniles a las disminuciones en la salinidad está sujeta a un control rítmico.

Las postlarvas responden a la disminución de la salinidad descendiendo al fondo en donde permanecen inactivas y evitan el desplazamiento a que las somete la marea menguante. Cuando la salinidad aumenta (pleamar) se mueven en la columna de agua y se desplazan hacia tierra.

La dependencia que existe al parecer entre los desplazamientos asociados con las mareas y los cambios en la salinidad parece sugerir la explicación de las correlaciones positivas que se han encontrado entre la amplitud de las precipitaciones fluviales en las vecindades de las zonas de cría y la captura comercial del año siguiente.

1 INTRODUCTION

Penaeus duorarum Burkenroad, like many species of penaeid shrimp, spends a considerable part of its life cycle in shallow waters, often in estuaries and other regions of freshwater run-off from the mainland. The shrimp, having hatched in the open sea, reach these nursery areas as postlarvae (approximately 1 cm in length). They spend from 4 to 7 mo in the inshore waters before again moving out, as juveniles (6 to 10 cm total length), to deeper waters where they will eventually spawn.

In southern Florida, the principal nursery areas for the pink shrimp are probably the waters within and surrounding the Everglades, while principal spawning sites are located on the Tortugas fishing grounds 130 to 185 km to the southwest (Munro, Jones and Dimitriou, 1968).

The purpose of this paper is to indicate the mechanism whereby the postlarvae move into the nursery areas (often deep within the Everglades) and the juveniles move out to the deep offshore waters.

2 EVIDENCE FOR TIDE-ASSOCIATED MOVEMENTS

Sampling was conducted in a channel leading into the Everglades by suspending three 'Discovery' type plankton nets from a bridge crossing the channel. Samples, each of 10 min duration, were taken at frequent intervals over periods of 6 h or more which included either a low or a high water. The results, of which examples are given in Fig.1, indicate that inshore transport of postlarvae and offshore transport of juveniles are associated directly with the flood and the ebb tides respectively. Postlarvae were collected predominantly in flood-tide samples, and juveniles were taken almost exclusively from ebb-tide samples. These results suggest that an important aspect of the movements carried out by postlarvae and juveniles is passively effected through displacement by the tides. Two important questions are raised however: What is the mechanism whereby ebb and flood tide are distinguished? What is the mechanism whereby the shrimp make use of one tide while avoiding displacement by the other?

3 RESPONSES OF SHRIMP TO SALINITY CHANGES

Water samples taken in the same channel from which the above results were obtained indicate that salinity changes occurring between the flood and ebb tides are seldom less than 7 to $10^{\circ}/_{oo}$, especially in the summer months, and frequently are as great as 15 to $20^{\circ}/_{oo}$ (Yokel, personal communication). Experiments were therefore carried out to assess the influence of changes in salinity on the behavior of both postlarvae and juveniles maintained in a current of water.

A plexiglass apparatus, similar to that designed by Creutzberg (1961) to study responses in migrating elvers, was used in these experiments. Essentially this is a cylinder 50 cm in diameter into which a second cylinder 25 cm in diameter is placed so that a channel of 12.5 cm in width is formed between them. A current is created in the channel by four paddles attached to a central axis, which is turned by a variable speed motor. There are small holes in the inner cylinder, with the result that any change in salinity within this cylinder produces a more gradual change in the salinity of the outer channel.

Shrimp were netted at night from a channel in the Everglades and placed several hours later in the current chamber. The following night their behavioral responses to varying current speeds and to salinity changes were recorded.

3.1 Juveniles

The juveniles usually showed a marked positive rheotaxis, orientating and swimming against the current. The swimming was effected in short hops off the sand substrate. They were able to maintain position against very strong currents, and, by partially burrowing under the sand, they could withstand any current which did not wash away the substrate.

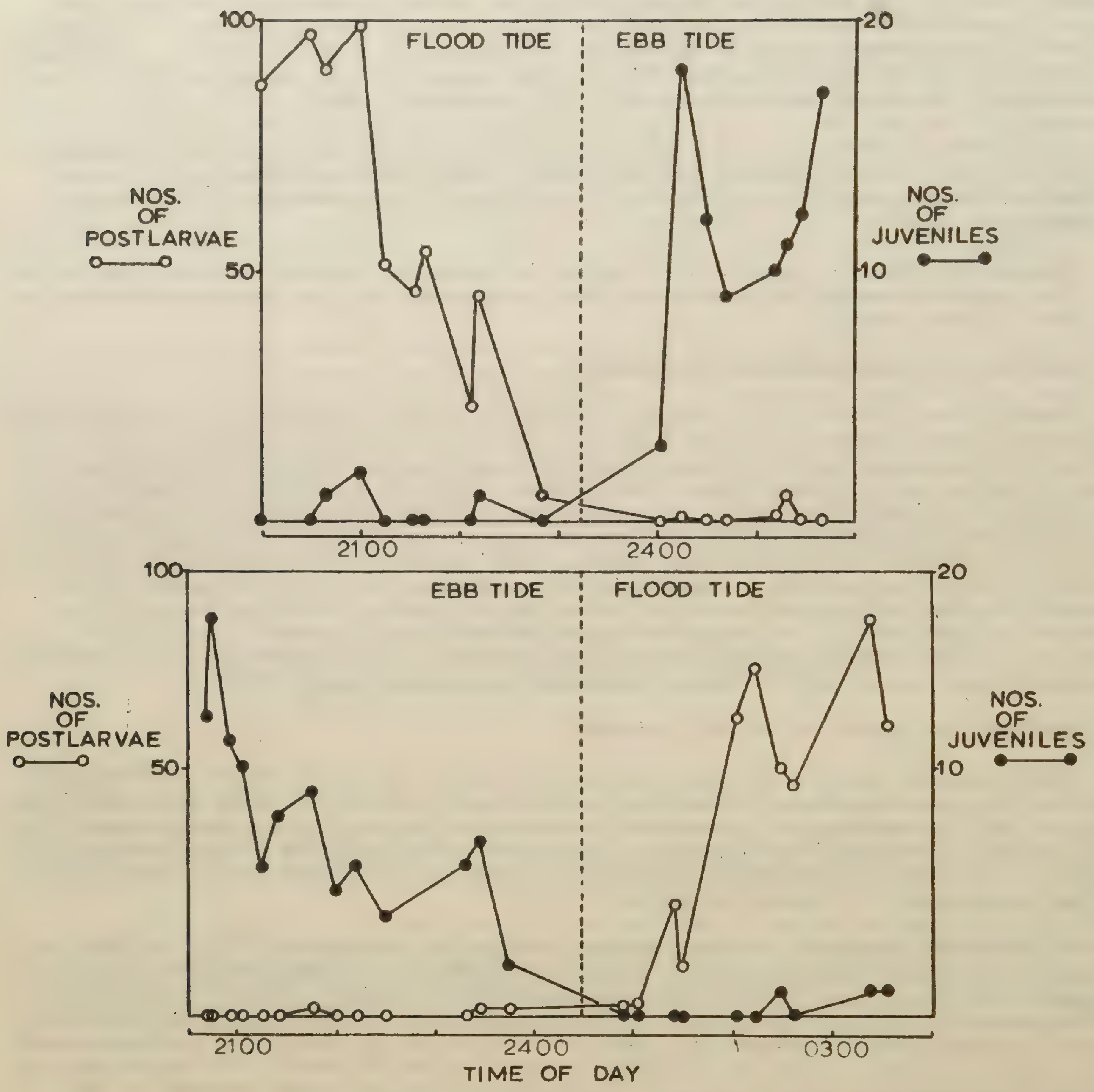

Fig. 1 Tide associated movements of postlarval and juvenile shrimp. The results of samples collected from part of a consecutive ebb and flood tide and a consecutive flood and ebb tide respectively. The approximate time of slack water is denoted by the dotted line. Each point represents the total number of shrimp caught in 10 min.

When, however, the salinity of the water was reduced (either by draining and refilling the chamber with water of lower salinity or by running distilled water into the water of the inner cylinder) the shrimp reversed their direction and either drifted or actively swam downstream (Fig. 2). A salinity decrease of $2^{o}/_{oo}$ would effect this response. An essential element was apparently the rate of decrease. A $2^{o}/_{oo}$ decrease occurring over 20 min was effective but the same decrease over a period of 40 min was not necessarily so. The time at which the decreases were imposed also was important in this connection (see section 4). Studies have shown that the downstream swimming which occurs as a result of salinity decrease may continue for less than 30 min or for up to 3 h.

Evidence for the control of the response and its duration by a biological rhythm is presented later (section 4).

3.2 Postlarvae

Unlike juveniles, postlarvae are not capable of swimming against strong currents and are easily displaced when active in the water column. However, a clear response to salinity changes (Fig. 3) was apparent. After a period of acclimation to a particular salinity, they become active in the water column. A reduction in salinity results in a reduction in activity: the postlarvae settle and become inactive on the substrate until the salinity is once more increased.

3.3 Tide associated movements as a consequence of responses to salinity changes

In the light of these results, it is possible to understand how changes in salinity between ebb and flood tides will affect the behavior of both postlarval and juvenile shrimp, and how these changes in behavior are the basis of the mechanism whereby displacements are effected by the tides.

The salinity of the flood tide is higher than that of the ebb. Under conditions of high salinity, juveniles exhibit a positive rheotaxis, orienting and swimming against the current in a series of short hops from the substrate. They will therefore not be displaced inshore by the tide, but may even make progress offshore.

The postlarvae, responding to the increased salinity, will be active in the water column. Due to their inability to maintain themselves against even slight current, they will be displaced in an inshore direction.

Due to the freshwater run-off from the Everglades, the salinity is decreased during the ebb tide. This decrease reverses the sign of the rheotactic response in juveniles. Instead of swimming against the current, they will swim or drift with it and thereby be carried in an offshore direction. Downstream swimming also differs from upstream swimming in that instead of moving in a series of short hops from the substrate, the shrimp usually remain within the water column for long periods. Under experimental conditions in the narrow channel, this swimming may be oriented by sight or touch. In nature, however, the downstream displacement is probably less oriented, and the shrimp, having begun to swim actively with the current, are thereafter swept by it.

When the salinity decreases during the ebb tide, postlarvae will become less active, settle on the substrate, and thereby be able to maintain their position against the current. In this way they will not be displaced offshore.

The above discussion shows how the simple responses to salinity changes are responsible for the inshore displacement of the postlarvae on the flood tide and the offshore displacement of juveniles on the ebb; at the same time these responses enable the shrimp to resist displacement by tides which would take them in reverse directions.

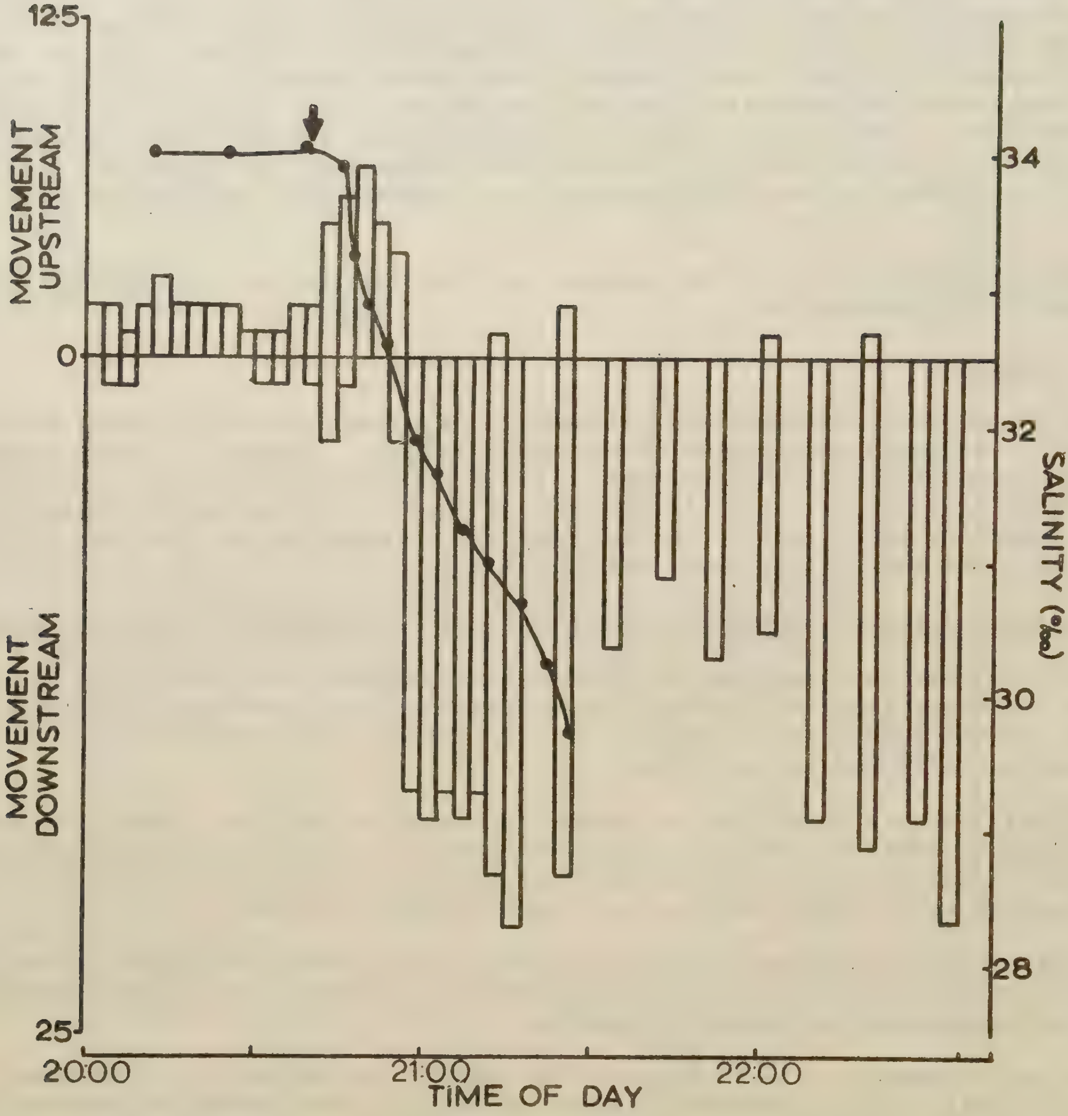

Fig. 2 Reversal of the direction of swimming of juveniles subjected to a decrease in salinity. Arrow shows time when salinity decrease was initiated; line shows salinity in current chamber. Movement is recorded as number of shrimp passing a vertical mark on current chamber in upstream or downstream direction during a two minute period.

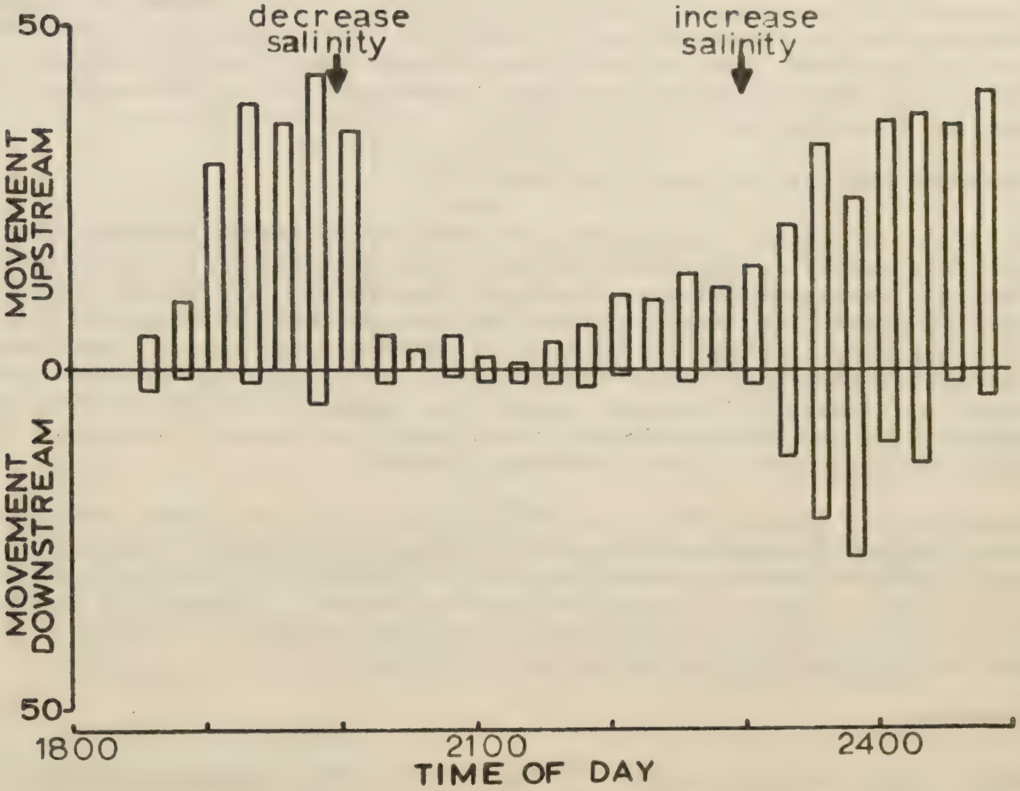

Fig. 3 Responses of postlarval shrimp to changes in salinity. The strength of the current was minimal and movement in either direction may be taken as an index of activity.

4 EVIDENCE FOR A RHYTHM CONTROLLING RECEPTIVITY TO SALINITY DECREASES IN JUVENILES

Results of preliminary experiments suggest that the response of juveniles to a decrease in salinity which is imposed at the time of the ebb tide elicits a more marked response than a decrease imposed at the time of the flood.

More conspicuous evidence of rhythmic influence is shown when downstream swimming occurs, even in the absence of a salinity decrease. This is shown in experiments where downstream swimming was observed in the early part of the evening on days following collection of the shrimp from an ebb tide occurring early in the evening, i.e. approximately 24 h after capture from an ebb tide occurring early in the evening, they would again swim downstream.

5 FRESHWATER RUN-OFF, RAINFALL AND MIGRATIONS

The results of these experiments have great relevance to the problems concerning the use of freshwater. These problems are being experienced by the Everglades and many estuaries, where agricultural usage and the drainage of rivers and marshes is reducing the freshwater flow through these areas. Salinity differences between the tides are apparently of great importance to the mechanisms whereby postlarvae are transported inshore on the flood tides and juveniles are transported offshore on the ebb tides. A reduction in salinity differences between the respective tides would probably result in a reduction in the effectiveness of postlarval and juvenile movements with possible far-reaching consequences to the commercial fishery.

Hildebrand and Gunter (1952) and Gunter and Hildebrand (1954) reported a close correlation between the commercial catch of Penaeus setiferus (Linnaeus) (= P. schmitt. Burkenroad) in Texas waters and the rainfall of the area in the previous year. This may be explicable in terms of the above considerations. Similarly, Iversen (personal communication) has shown a correlation between the rainfall in Florida and the commercial catch of Penaeus duorarum during the following year.

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THE RELATION OF RAINFALL AND FRESH-WATER DRAINAGE TO THE PRODUCTION OF THE PENAEID SHRIMPS (*Penaeus fluviatilis* SAY AND *Penaeus aztecus* IVES) IN TEXAS AND LOUISIANA WATERS

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Abstract

The catch of white shrimp off Texas from 1927 to 1964 showed a strong statistical correlation with the total rainfall of the state, the highest correlations being (i) between the year's catch and the rainfall of the previous two years and (ii) between the year's catch and the combined rainfall of the year and the previous two years.

No correlation was found between catches of brown shrimp and rainfall in Texas, or between catches of either species in Louisiana and the outflow of the Mississippi and Atchafalaya Rivers.

The results are discussed in relation to the behaviour of larvae and postlarvae of white and brown shrimp.

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RAPPORT ENTRE LES PLUIES ET LE RUISSELLEMENT ET LA PRODUCTION DES CREVETTES *Penaeus fluviatilis* SAY ET *Penaeus aztecus* IVES DANS LES EAUX DU TEXAS ET DE LA LOUISIANE

Résumé

Les prises de *Penaeus fluviatilis* au large du Texas de 1927 à 1964 manifestent une forte corrélation statistique avec le total des chutes de pluie dans cet Etat, et plus particulièrement: (i) entre les prises de l'année et les précipitations des deux années précedentes; (ii) entre les prises de l'année et les pluies globales de l'année et des deux années précédentes.

Il n'a pas été révélé de corrélation entre les captures de *Penaeus aztecus* et les chutes de pluie au Texas, ni entre les prises des deux espèces en Louisiane et l'apport du Mississippi et de l'Atchafalaya.

Les résultats sont examinés en liaison avec le comportement des larves et des postlarves de *Penaeus fluviatilis* et de *P. aztecus*.

LA RELACION ENTRE LA LLUVIA Y LA ENTRADA DE AGUA DULCE CON LA PRODUCCION DE PENEIDOS (*Penaeus fluviatilis* SAY Y *Penaeus aztecus* IVES) EN LAS AGUAS DE TEXAS Y LOUISIANA

Extracto

Las capturas de camarón blanco en aguas de Texas desde 1927 a 1964 señalaron una gran correlación estadística con las precipitaciones totales en el Estado, siendo las mayores correlaciones entre (i) la captura del año y las lluvias de los dos años anteriores y (ii) entre la captura del año y las precipitaciones combinadas de tal año y de los años anteriores.

No se encontró ninguna correlación entre las capturas de camarones café y las lluvias en Texas, o entre las capturas de ambas especies en Louisiana y la descarga de las aguas de los ríos Mississippi y Atchafalaya.

Se discuten los resultados en relación con el comportamiento de las larvas y las postlarvas de los camarones blanco y café.

1 INTRODUCTION

Marine biologists and fishery workers on the Gulf Coast remember when scientists considered the Gulf of Mexico to be a warm semitropical, clear and barren sea - a Mediterranean - which would never amount to much in terms of fishery production. It was thought that insufficient nutrients entered the Gulf to support large populations of animals. This type of appraisal was still being made public after the Gulf States Marine Fisheries Commission was organized in 1949. The errors of this concept were discussed at the meeting of the Commission in Louisiana in October 1966.

Actually, the situation was quite the opposite. Gunter (1963), showed that coastal waters from Pascagoula, Mississippi, to Port Arthur, Texas, produce 20 percent of the fishery products of the United States, and he named this region "The Fertile Fisheries Crescent". The Gulf of Mexico produces 28 to 30 percent of the total fishery products of the United States. Gunter (1963) showed that between 1936 and 1962 Alaska fishery production decreased by over 50 percent, the production of Pacific Coast States declined by 66 percent, and that of the Atlantic Coast increased by 33 percent. In the same period, production from the Gulf Coast increased by 700 percent, or 7 times its former production.

The shrimp fishery of the southern states of the U.S.A. depends mostly upon species of the family Penaeidae and is the most valuable in the country. Landings at ports in Texas, Louisiana and the west coast of Florida regularly amount to 80 percent of the southern states shrimp catch (ANON., 1966). Total southern states production in 1965 amounted to about 215 million lb (97.7 million kg) (heads-on weight). (There are small shrimp fisheries in Maine, Oregon, Washington, and Alaska, depending upon the family Pandalidae, that vary from 1 to 10 million lb (0.4-4.5 million kg) per year.)

Histories of the shrimp fisheries are given in various places (Anderson, Lindner and King, 1949; Bullis, 1955; Springer, 1951).

Originally, the white shrimp (Penaeus fluviatilis Say) was caught in the Gulf States by cast-nets, then haul seines were introduced in Louisiana. Some of these were 1,000 fm (1830 m) long, and were operated by a crew of 32 men. Otter trawls were introduced in 1917 and from then on the fishery changed rapidly. Since that time the sizes of boats, nets and machinery have all increased greatly, and the refrigeration process has been greatly expanded and improved. The white shrimp could not support the full demand and soon after the second world war, two other species, the brown shrimp (Penaeus aztecus Ives) and the pink or spotted shrimp (Penaeus duorarum Burkenroad) were exploited by the fishery.

Pink shrimp are taken mostly in Florida and the Gulf of Campeche. Brown shrimp are caught predominantly in Texas waters, whereas the white shrimp are taken predominantly in Louisiana waters.

According to the Commercial Fishery Review (ANON., 1966) Texas led all states in 1965 with a production of 48.3 million lb (22 million kg) (heads-off weight), followed by Louisiana with 39.8 million lb (18 million kg) and the Florida west coast with 23.6 million lb (10.7 million kg). The Florida west coast catch included 21.5 million lb (9.8 million kg) of pinks. Louisiana reported 21.2 million lb (9.6 million kg) of white shrimp and 18.0 million lb (8.2 million kg) of browns. Texas produced 34.0 million lb (15.4 million kg) of brown shrimp and 14 million lb (6.4 million kg) of whites.

For the period 1956 to 1959, Louisiana led in white shrimp landings and Texas led in brown shrimp (Gunter, 1962). The white and brown shrimp are of little importance in Florida. During the same four-year period, Florida landings of pink shrimp amounted to 23 million lb (11 million kg) per year or 96.6 percent of the Gulf pinks caught. This shrimp is of little importance in the other states.

In terms of percentage of total Gulf landings, the rank of these three Gulf states for the four-year period was: Texas 41.5, Louisiana 24.7, and Florida 23.6.

For the period 1956 to 1959, the annual average landings of heads-off shrimp in Texas was 4.6 million lb (2.1 million kg) for white and 39.1 million lb (17.8 million kg) for brown; while Louisiana produced 13.3 million lb (6.0 million kg) of white shrimp and 11.9 million lb (5.4 million kg) of brown shrimp.

The general life history of the shrimp has been worked on by several investigators. It has been properly understood and described only in the past 17 years (Gunter, 1950; Lindner and Anderson, 1956; Williams, 1955). In brief, shrimp spawn at sea, but the young develop in bays and are restricted to the low salinity estuarine areas. Small shrimp of the three dominant commercial species migrate into these areas not only in different seasons, but also they prefer different salinities or have different salinity optima. Data supporting this conclusion have been summarized and discussed by Gunter, Christmas, and Killebrew (1964).

Apparently the pink shrimp young occur in the highest salinities, browns in intermediate, and white shrimp in the lowest salinities. Thus, as we might expect, the largest production of white shrimp is in Louisiana waters in the low salinity estuarine areas created by the outflow of the Mississippi River. The largest brown shrimp production comes from the drier, higher salinity Texas coast.

2 PROBLEM

Ezekiel (1942) observed that rainfall was a limiting factor to cotton production in Texas, apparently because there was never quite enough of it, but it was not a limiting factor to cotton production in Louisiana. This caused Gunter to investigate the same problem with regard to the white shrimp in Texas. The problem was treated in two papers, Hildebrand and Gunter (1953) and Gunter and Hildebrand (1954). These two papers showed practically the same results. The second paper gave estimates of the shrimp catch for 1933 and 1935, for which there were no available data, and the catch for 1952, which had not been included in the first paper. Thus a longer series was involved.

The period of time covered one of high business activity followed by a depression, slight recovery, recession, a war and high economic activity ever since. The price index was low in the beginning and increased with the catch, but it fell off sharply after 1947. Technological improvements continued as the catch fell. The only correlation with the catch that can be recognized over this series of years is with rainfall, and the highest correlation is that between the catch of the year and the rainfall of that year and the two previous years.

There are some physical and biological reasons why this correlation is better than that of the catch with the rainfall of the same year. There is a lag period of the river flow determined by dryness of the soil and by the distance of the upper regions of the rivers. There is also a damping of salinity changes in the bays after one particular salinity regime is already established. Then too, a great many of the shrimp survive the winter and a few may even survive for two years. Lastly, some of the rainfall of the year occurs months after the main shrimp season is over, that is to say, after the greatest part of the shrimp catch of the year has been taken.

The present work reexamines this problem on a fourfold basis. The first step is a reexamination of the white shrimp catch and rainfall correlation in Texas with a longer series of data (38 years) than was used by Gunter and Hildebrand (1954). The other three steps are an attempt to discover if there is a relationship between the brown shrimp catch in Texas and the rainfall, and similarly to determine if there is any correlation between the outflow of the Mississippi-Atchafalaya river system in Louisiana and the catch of white and brown shrimp in that state.

3 DATA AND RESULTS

3.1 White shrimp production and rainfall in Texas

Annual average rainfall and shrimp landings on the Texas coast for the years 1927 to 1964 are compared in Fig. 1 to 4. The figures from 1927 to 1952 were taken from Gunter and Hildebrand (1954). Catches for the remaining years were taken from the Fishery Statistics of the United States (Fish and Wildlife Service). Data on Texas annual average rainfall for the years 1953 to 1964, inclusive, were obtained from Dr.B.J. Copeland of the Institute of Marine Science, The University of Texas, Port Aransas. (Dr. Copeland computed these figures from 600 stations in Texas for another purpose, and we are grateful for his assistance). Estimates of the bait shrimp catch from 1959 to 1964 were made from information provided by the Bureau of Commercial Fisheries Biological Laboratory at Galveston and the Texas Parks and Wildlife Commission. These figures were added to those for commercial landings because we were interested in total catch.

The correlation between the rainfall and the shrimp landings for various combinations of years has been statistically treated and the results are presented in Table I.

TABLE I

Correlations and significance levels between annual white shrimp catch and annual rainfall for the State of Texas, 1927-1964

Years compared	Degrees of freedom	r	SIGNIFICANCE 10%	5%	1%	0.1%
Catch and rainfall, same year	36	.301	.271	.321	.413	.513
Catch with rainfall of year and year before	35	.505	.275	.325	.418	.519
Catch with rainfall of the two previous years	34	.673	.279	.330	.424	.526
Catch with rainfall of year and two years before	34	.656	.279	.330	.424	.526

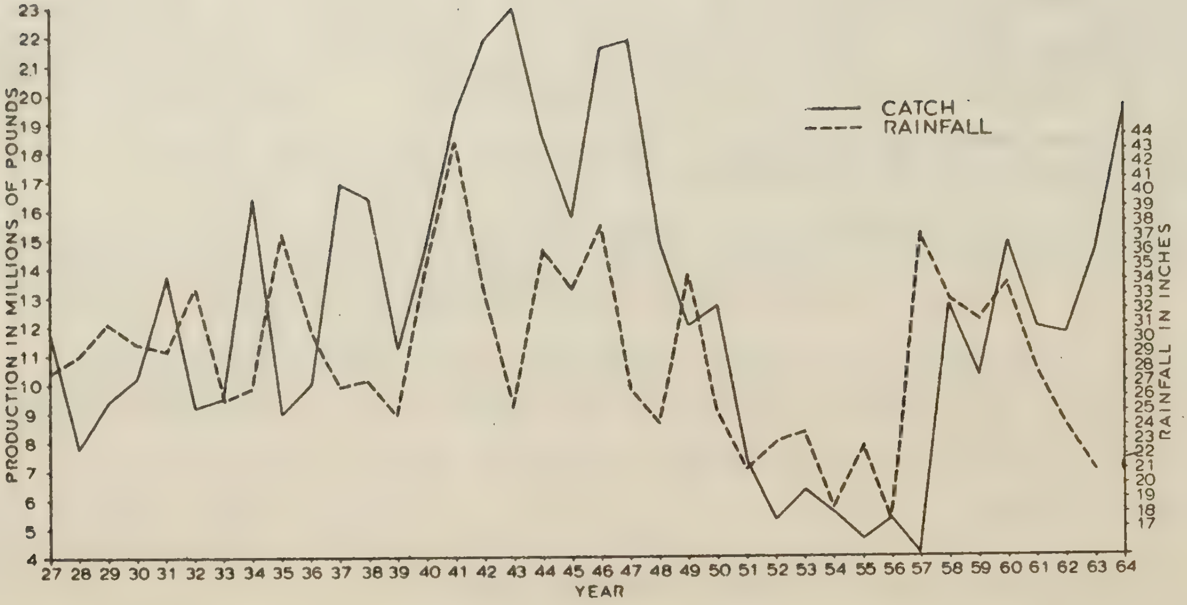

Fig. 1 Relationship between the annual catch of white shrimp and the average annual rainfall, of the same year, for the State of Texas.

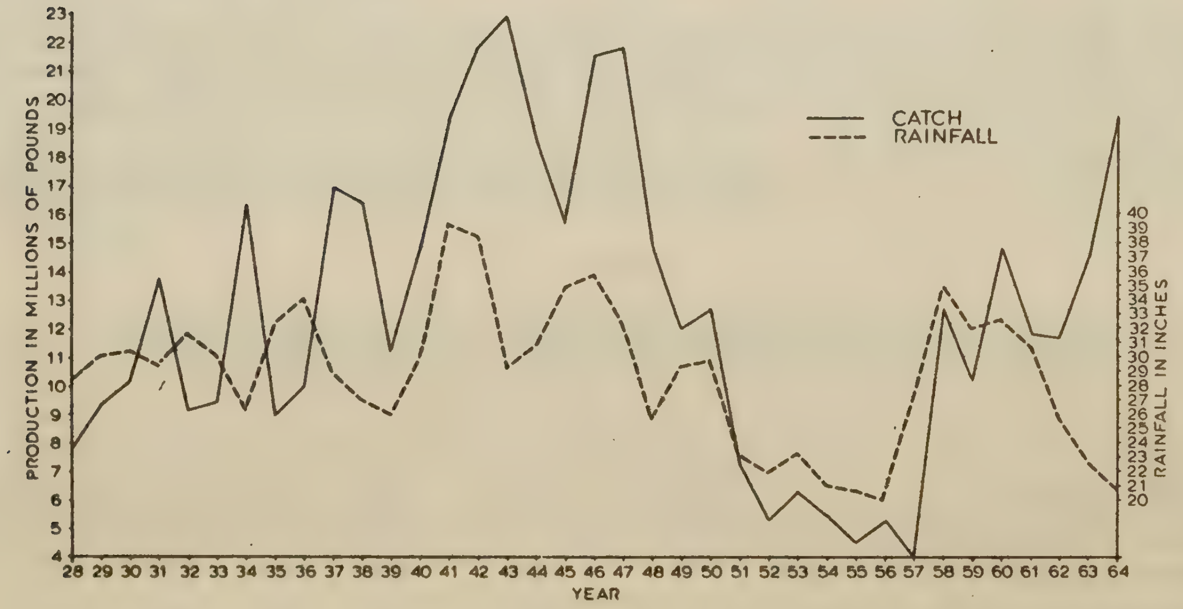

Fig. 2 Relationship between the annual catch of white shrimp and the average annual rainfall, of the same year and the previous year, for the State of Texas.

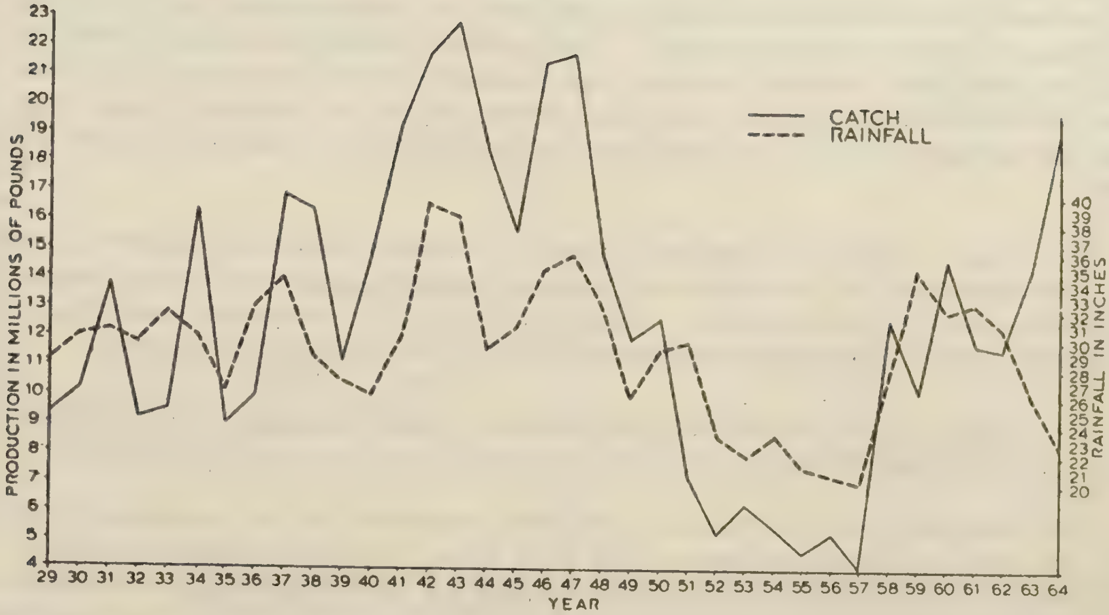

Fig. 3 Relationship between the annual catch of white shrimp and the average annual rainfall, of the two previous years, for the State of Texas.

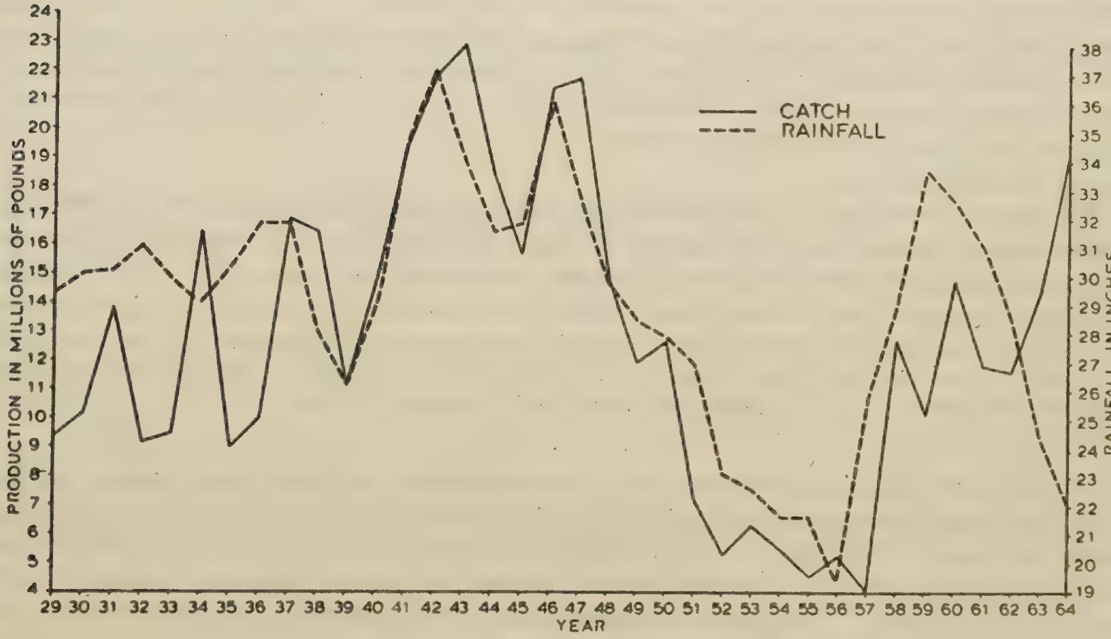

Fig. 4 Relationship between the annual catch of white shrimp and the average annual rainfall, of the same year and two previous years, for the State of Texas.

It can be seen from Table I that the correlation between the year's catch and the rainfall of the same year was significant only at the 10 percent level. The correlation between the catch of the year and rainfall of the same and the previous year were significant at the 1 percent level. The highest correlation, significant at 0.1 percent, was seen when the year's catch was correlated with the rainfall of the two previous years. A close correlation, also significant at the 0.1 percent level, was found between the average rainfall for the year and two previous years as related to the year's catch.

From these results, it becomes clear that over a period of 38 years, from 1927 to 1964, the catch of the white shrimp, Penaeus fluviatilis, on the Texas coast is positively correlated with the rainfall. The conclusions of the earlier authors (Hildebrand and Gunter, 1953; Gunter and Hildebrand, 1954) are strongly confirmed.

3.2 White shrimp production and outflow of the Mississippi River System into Louisiana waters

The Mississippi River drains water from one-third of the continental United States. There are two main distributaries, the main river, and the Atchafalaya River. The water these two rivers discharge into Louisiana bays is of overwhelming importance as compared to the local rainfall in its effect on the salinity. Therefore, the mean daily discharge of the two rivers was used in an effort to determine whether the discharge rate bore a relation to the production of white shrimp in Louisiana waters. This discharge occurs at the rate of several millions of ft^3/s.

Data on the annual catches of shrimp in Louisiana have been taken from the Fishery Statistics of the United States, except for the years 1933 and 1935, and the years 1941 to 1947, which were based on tax records of Louisiana. The publication, Annual Maximum, Minimum, and Mean Discharges of the Mississippi River and its Outlets and Tributaries to 1953, by the Mississippi River Commission, Vicksburg, was the source for the mean river discharge data through 1953. Data for 1954 to 1964 were supplied by the New Orleans District, U.S. Army Corps of Engineers.

The annual landings of white shrimp and the daily average flow of the Atchafalaya and Mississippi Rivers are presented in Fig. 5 to 8, and the results of the statistical analysis of these figures for correlations are given in Table II. The data show no significant correlation between the shrimp catches and the flow of these rivers. When the r values for the four sets of criteria are examined (Table II), it becomes evident that there is no correlation even at the 10 percent level. The two factors follow independent patterns of fluctuations from 1927 through 1964.

This situation is in contrast to the conditions on the Texas coast, where increased rainfall and the consequent dilution of the coastal waters results in augmented catches of white shrimp. Similar to the findings of Ezekiel (1942) in relation to cotton production, high salinity (low fresh water inflow) is not a limiting factor to shrimp production in Louisiana. On the Louisiana coast, the increase or decrease of river discharge does not appear to affect the catches.

One more point deserves some consideration. The Louisiana shrimpers have always been leaders in the Gulf and their boats have ranged far and wide. However, when they go to Campeche and Florida, they catch pink shrimp, and when they go to Texas, they catch

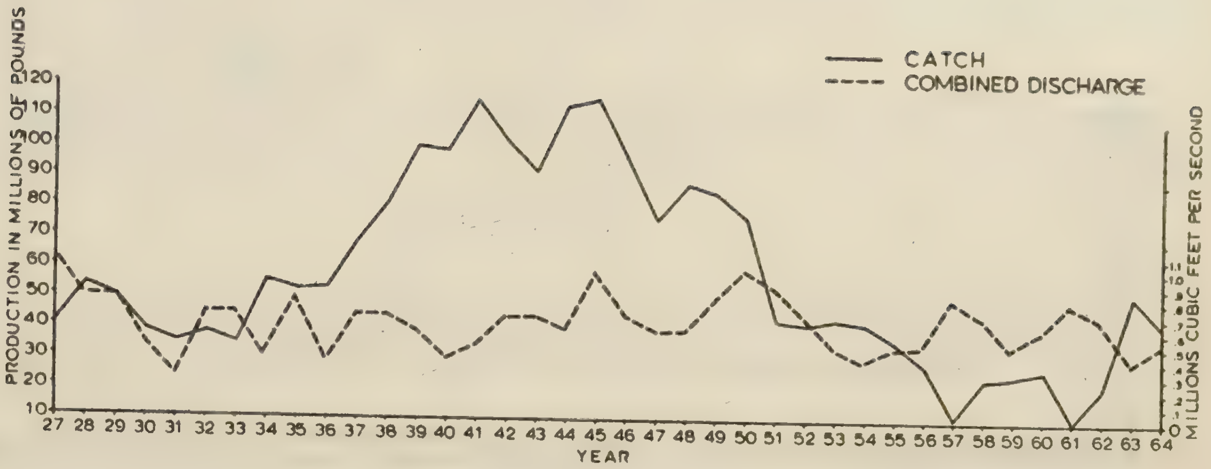

Fig. 5 Relationship between the annual catch of white shrimp and the combined daily average discharge of the Atchafalaya and Mississippi Rivers into Louisiana waters, for the same year.

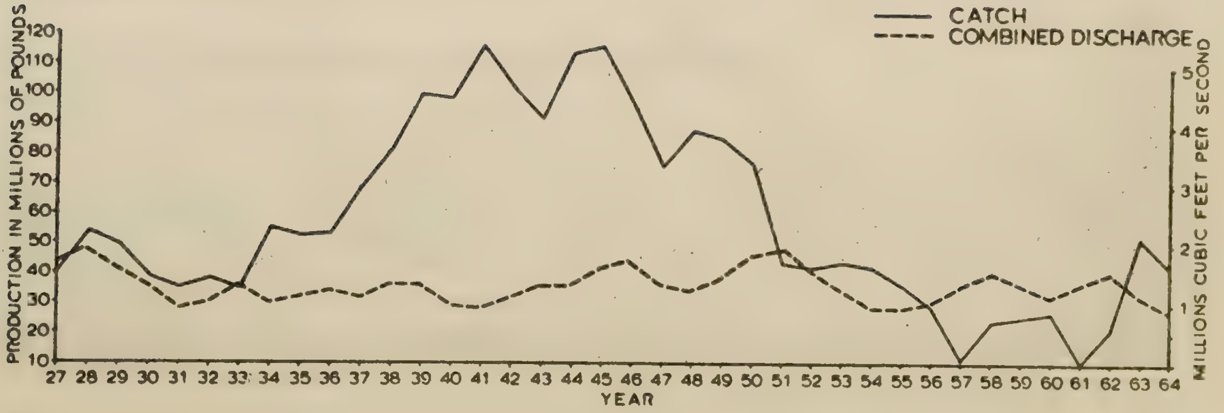

Fig. 6 Relationship between the annual catch of white shrimp and the combined daily average discharge of the Atchafalaya and Mississippi Rivers into Louisiana waters, for the same year and previous year.

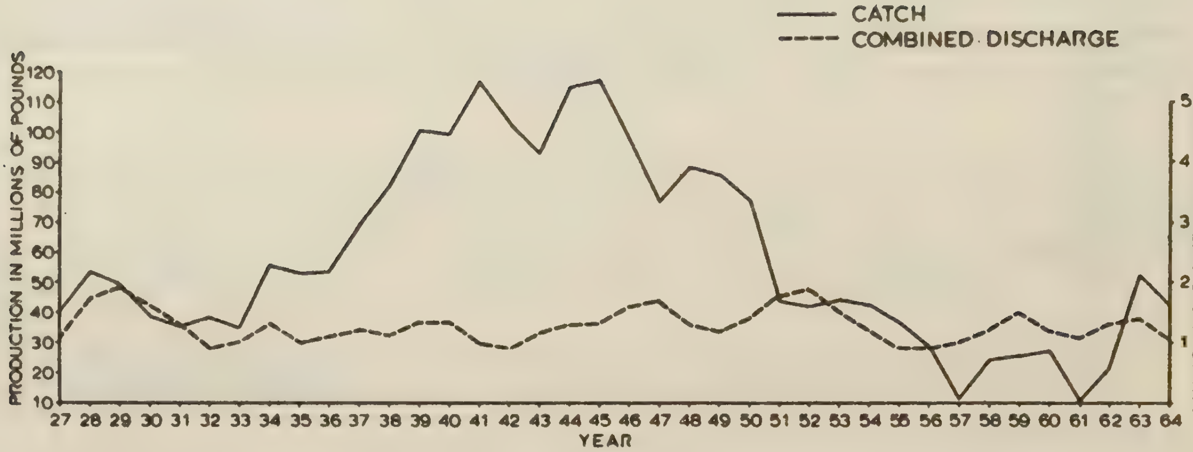

Fig. 7 Relationship between the annual catch of white shrimp and the combined daily average discharge of the Atchafalaya and Mississippi Rivers into Louisiana waters, for the two previous years.

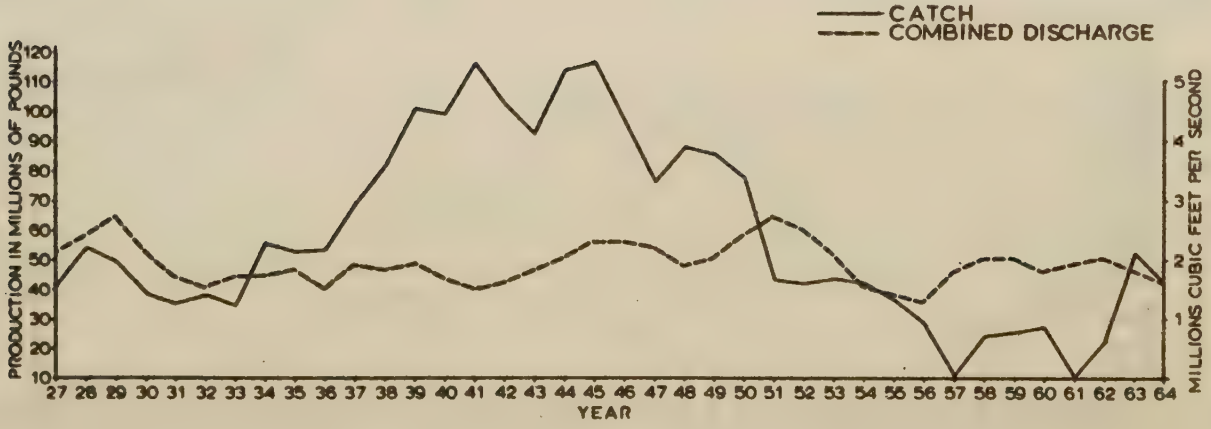

Fig. 8 Relationship between the annual catch of white shrimp and the combined daily average discharge of the Atchafalaya and Mississippi Rivers into Louisiana waters, for the same year and two previous years.

mostly brown shrimp. The figures given above are mostly landings, but the large majority of the white shrimp were taken in Louisiana. It is unlikely that white shrimp catches from outside of the state would be high enough to have a significant effect on the figures of white shrimp production for Louisiana.

Probably the minimum flow of the rivers every year is sufficient for the white shrimp populations on the Louisiana coast, and presumably the fluctuations in the catches are due to other factors.

TABLE II

Correlations and significance levels between annual white shrimp catch and the combined daily average discharge of the Atchafalaya and Mississippi Rivers into Louisiana waters, 1927-1964

Years compared	Degrees of freedom	r	Significance 10% level
Catch with combined discharge, same year	36	.067	.271
Catch with combined discharge, of year and year before	36	.044	.271
Catch with combined discharge of two previous years	36	.029	.271
Catch with combined discharge of year and two years before	36	.074	.271

3.3 Brown shrimp catch and rainfall in Texas waters

As stated in the introduction, the white shrimp population was not of sufficient strength to support the demand for shrimp after a vigorous program of selling and advertising had carried the Gulf shrimp into markets throughout the U.S.A. The brown shrimp were introduced into the market by Texas cooperative associations in 1948, and since then annual production of brown shrimp has consistently surpassed that of white shrimp. Although we do not have a long series of years with which to work, it was thought worthwhile to examine the relationship between the production of brown shrimp and the rainfall of the state.

Gunter (1962) has shown that brown shrimp account for approximately 60 percent of the Texas shrimp landings and Gunter, Christmas and Killebrew, (1964) reported that brown shrimp are most abundant off the Texas coast.

The bait shrimp catch from 1959 to 1964 was estimated from information given the Bureau of Commercial Fisheries Laboratory at Galveston and the Texas Parks and Wildlife Commission. These figures were added to the commercial landings of brown shrimp.

TABLE III

Correlations and significance levels between annual brown shrimp catch and annual rainfall for the State of Texas, 1948-1964

Years compared	Degrees of freedom	r	Significance 10% level	Significance 5% level
Catch and rainfall, same year	15	-.002	.412	.482
Catch with rainfall of year and year before	15	-.122	.412	.482
Catch with rainfall of the two previous years	15	-.351	.412	.482
Catch with rainfall of year and two years before	15	-.269	.412	.482

Comparisons between the annual catch and average rainfall are shown in Fig. 9 to 12. The pattern of fluctuations of the two factors between 1948 and 1964 shows no correlation. Statistical treatment of the catches of the year and (i) the same year's rainfall, (ii) rainfall of the year and the previous year, (iii) rainfall of the two previous years, and (iv) rainfall of the year and the two previous years, shows this point beyond doubt. The r values range from -.002 to -.351 (Table III), indicating no significant correlation. However, a longer series of data may show a significant negative correlation between catch and rainfall, which would be expected of a shrimp adapted to a dry, high salinity coast.

3.4 Brown shrimp production and outflow of the Mississippi River System into Louisiana waters

The Louisiana brown shrimp production or catch data are available for only a few years. The available data on browns are presented in Fig. 13 to 16. It can be seen from Table IV that the shrimp catches have no correlation to the river discharge over the years 1956 to 1964, the r value being -.485. The fluctuations follow a random pattern for both factors.

When the average daily river discharge (i) for the same year, (ii) for the year and the previous year, (iii) for the two previous years and (iv) for the year and the two previous years are examined in relation to brown shrimp landings, it is obvious that no correlation exists between them. The four values range from 0.033 to -.485.

Brown shrimp populations are apparently not affected significantly by the river flow. On the other hand, indications are that a negative correlation might become apparent with a longer series of data.

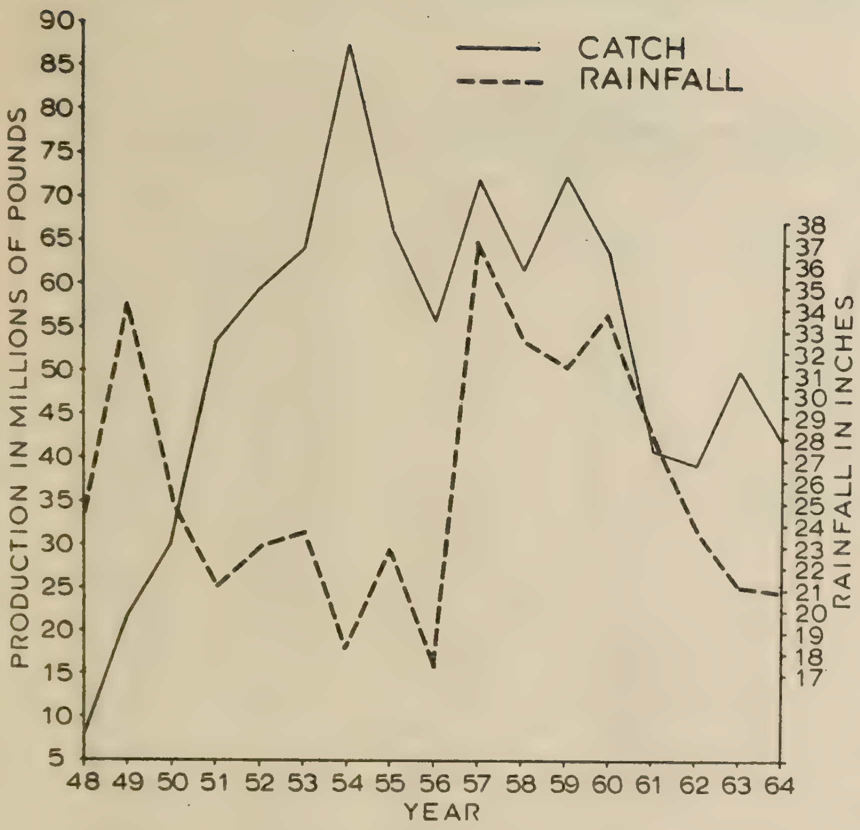

Fig. 9 Relationship between the annual catch of brown shrimp and the average annual rainfall, of the same year, for the State of Texas.

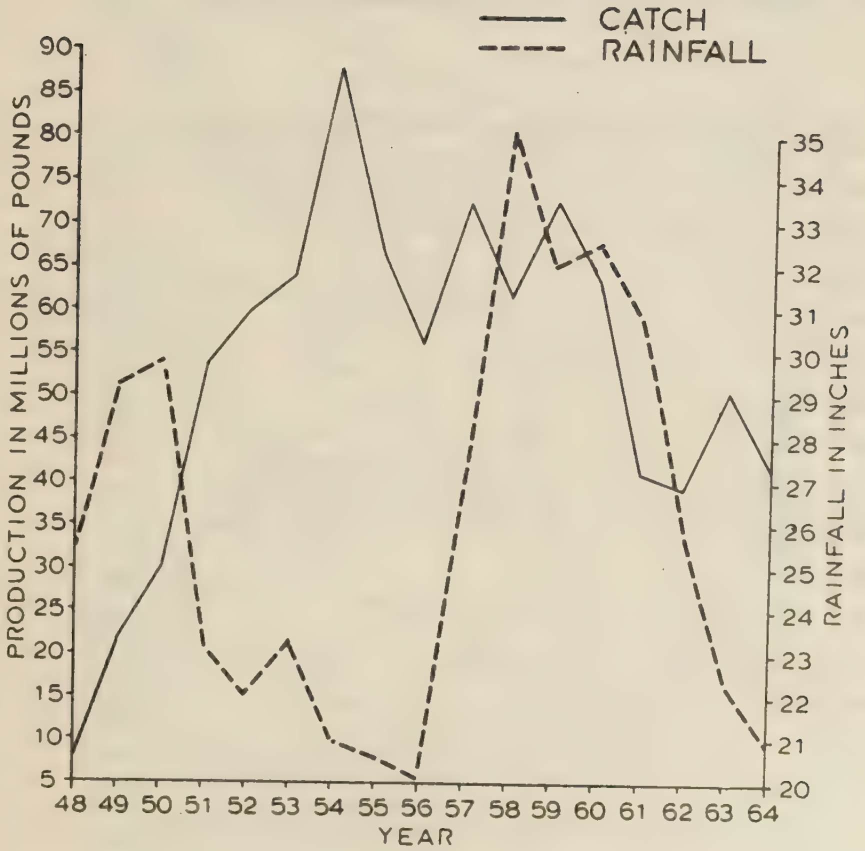

Fig. 10 Relationship between the annual catch of brown shrimp and the average annual rainfall, of the same year and the previous year, for the State of Texas.

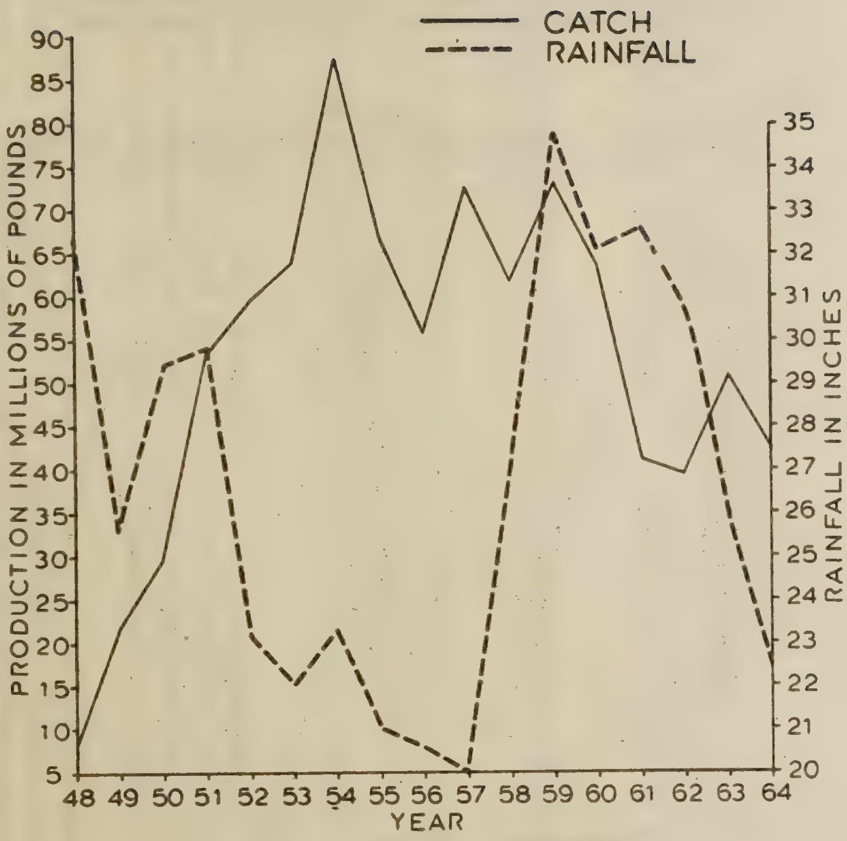

Fig. 11 Relationship between the annual catch of brown shrimp and the average annual rainfall, of the two previous years, for the State of Texas.

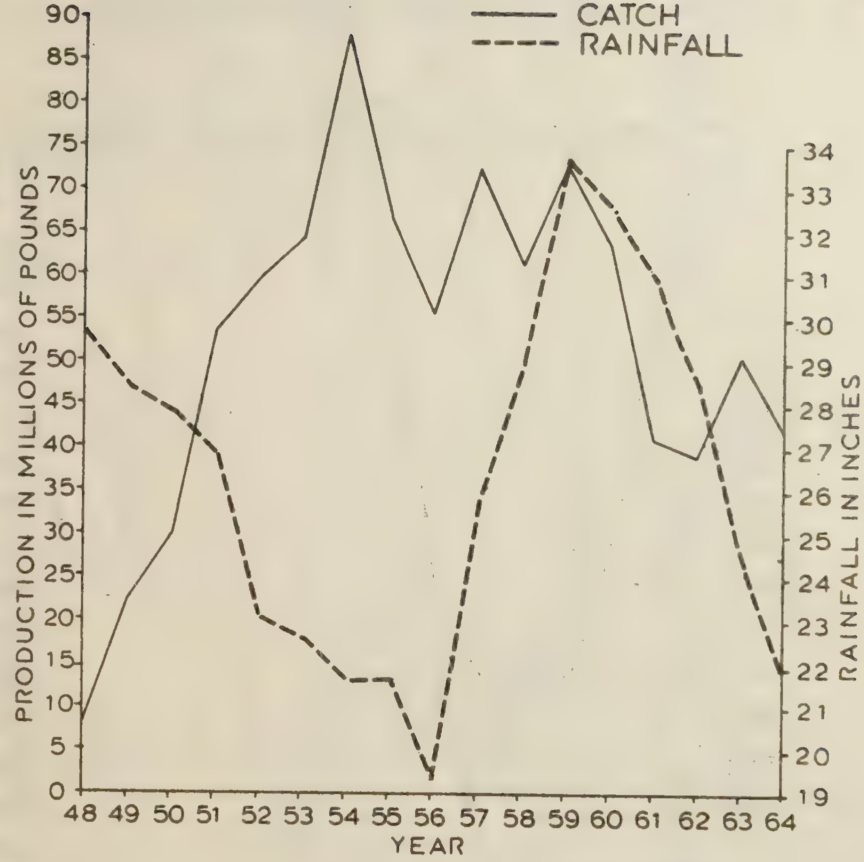

Fig. 12 Relationship between the annual catch of brown shrimp and the average annual rainfall, of the same year and two previous years, for the State of Texas.

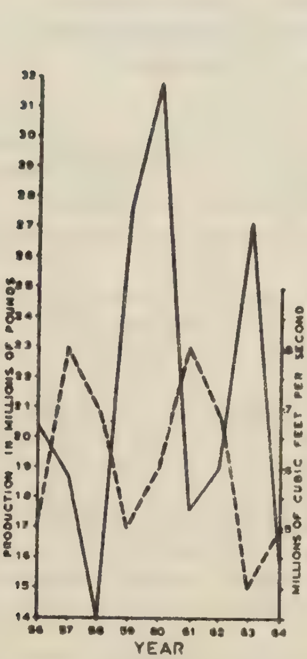

Fig. 13

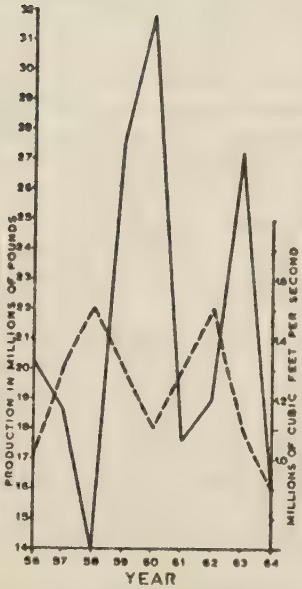

Fig. 14

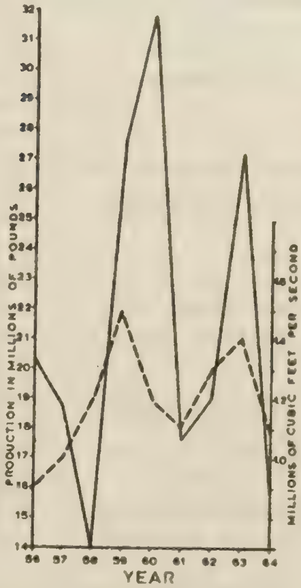

Fig. 15

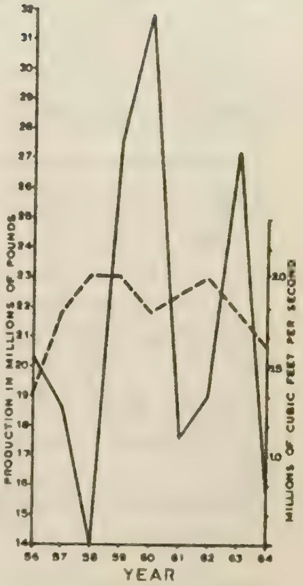

Fig. 16

Fig. 13	Relationship between the annual catch of brown shrimp and the combined daily average discharge of the Atchafalaya and Mississippi Rivers into Louisiana waters, for the same year.
Fig. 14	Relationship between the annual catch of brown shrimp and the combined daily average discharge of the Atchafalaya and Mississippi Rivers into Louisiana waters, for the same year and previous year.
Fig. 15	Relationship between the annual catch of brown shrimp and the combined daily average discharge of the Atchafalaya and Mississippi Rivers into Louisiana waters, for the two previous years.
Fig. 16	Relationship between the annual catch of brown shrimp and the combined daily average discharge of the Atchafalaya and Mississippi Rivers into Louisiana waters, for the same year and two previous years.

TABLE IV

Correlations and significance levels between annual brown shrimp catch and the combined daily average discharge of the Atchafalaya and Mississippi Rivers into Louisiana waters, 1956-1964

Years compared	Degrees of freedom	r	Significance 10% level	Significance 5% level
Catch with combined discharge same year	7	-.485	.582	.666
Catch with combined discharge of year and year before	7	-.279	.582	.666
Catch with combined discharge of two previous years	7	.484	.582	.666
Catch with combined discharge of year and two years before	7	.033	.582	.666

4 DISCUSSION

Penaeid shrimps have efficient osmoregulation processes (Robertson, 1960). Different species show different salinity preferences, but the role salinity plays in governing the populations is not fully understood. Moreover, river discharge and land drainage may also affect temperatures of coastal waters, and whether this correlates with the production trends has not been investigated.

White and brown shrimp spawn offshore in high salinity waters of the open Gulf and the postlarvae inhabit the low salinity waters. The browns grow to a size of 90 to 100 mm in three months, and the whites grow up to 150 mm in six months. These young adults support the coastal fishery. Fluctuations in annual catches may be due to factors such as rainfall, recruitment, mortality in the natural populations, or movements of shrimp away from the general fishing grounds. The exact relationship between the ecological factors and the movements of the shrimp populations is not yet understood.

The data show that white shrimp production has a positive correlation with rainfall in Texas and also that there is a significant lag effect. That is to say, the catch is correlated with rainfall of the previous two years on the Texas coast. Brown shrimp production shows no such relationship. On the contrary, neither the white shrimp nor the brown shrimp catches off Louisiana fluctuate in relation to the river discharge. Though the principle involved is the same, i.e. dilution of coastal waters due to land drainage after rains or increased river flow, it is interesting that white shrimp production should exhibit a different correlation in Texas to that on the Louisiana coast. Gunter, Christmas and Killebrew, (1964) have shown that small white shrimp prefer salinities below $10^{o}/oo$. Therefore, increased rainfall and dilution of coastal waters might prove more favorable to white shrimp in Texas, as has been pointed out by Gunter and Hildebrand (1954). The lag effect in production may be due in part to a lag in the rise and fall of salinity of coastal and offshore waters following wet and dry spells.

Johnson and Fielding (1956) have shown experimentally that low salinity, per se, is not necessary for the survival and growth of the white shrimp under artificial conditions. However, the fact that increased rainfall is followed by a greater catch of white shrimp off the Texas coast has been shown in this study and those of earlier investigators. The fact that Louisiana white shrimp production shows no correlation with river discharge may appear to be contradictory. However, there is a high minimum discharge of the rivers along the Louisiana coast, and the white shrimp is the dominant species. There may be a population well adapted to this environment, and more river discharge may not affect the situation except to induce the whites to move farther down the bays. While less saline waters off the Texas coast may favor a white shrimp migration inshore, because the waters are definitely more salty, increased river discharge may have exactly the opposite effect off Louisiana. In any case this correlation is apparently related with salinity per se or some factor governed by salinity.

Gunter, Christmas and Killebrew (1964) have shown that the small brown shrimp are abundant in salinities between 10 to 20°/oo. They also state that "small shrimp have optimum salinities, which are different for different species, and which they select after entering the bays, although this selection may be entirely passive". It appears, therefore, that the increased rainfall off Texas and more river discharge off Louisiana might cause the abundance of brown shrimp to decline, by reducing the salinities of the inshore waters to below the optimum for the species. Possibly, this explains the suggested negative correlation of brown shrimp production and river flow in Louisiana.

From the present study, it appears that the white shrimp catch off the Texas coast is positively correlated with the rainfall of the state, but the browns exhibit no such correlation.

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E/50

Pandalus borealis IN GREENLAND WATERS: ITS FISHERY AND BIOLOGY

by

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Abstract

The Greenland deep-sea prawn fishery started in 1935, and since the second world war it has become a very important industry with factories in many towns.

The prawns are widely distributed in Greenland waters, where they live on soft bottoms at depths mainly from 150 to 500 m and mainly at temperatures from 1 to 2°C. Their development and growth are relatively slow compared with stocks in more southern and warmer waters; change from males to females does not take place until they are 4 or 5 yr old. They play an important role in the food chain, and they seem to have a high natural mortality due to many fish predators.

Regular and irregular natural fluctuations in stock density (and trawl catches) have been observed, mostly caused by variations in water temperature. The inflow of warm bottom water from the Davis Strait helps to transport large quantities of prawns to the trawling grounds in the fjords and other inshore areas. Exceptionally cold water may destroy a local stock, as was the case in the fjords at Holsteinsborg in the winter of 1949.

Fluctuations in trawl catches are mostly due to natural variations in stock density, and overfishing does not seem to be a problem in Greenland at present. However, it is desirable to avoid undersized prawns in the catches, and the most effective measure would be to encourage trawling in deep water, where the big prawns predominate, while the undersized are most numerous in shallower water.

E/50

Pandalus borealis DES EAUX GROENLANDAISES: PECHE ET BIOLOGIE

Résumé

La pêche groënlandaise de la crevette nordique (Pandalus borealis), qui a commencé en 1935, est devenue depuis la Seconde Guerre mondiale une industrie très importante alimentant des usines dans de nombreuses villes..

Les crevettes sont largement réparties dans les eaux du Groënland, où elles habitent les fonds mous, à des profondeurs s'étageant surtout entre 150 et 500 mètres, et principalement dans des zones où la température va de 1 à 2°C. Leur développement et leur croissance sont lents par rapport à ceux des stocks occupant des eaux plus méridionales et plus chaudes; l'inversion du sexe (de mâle à femelle) ne se produit pas avant l'âge de 4 ou 5 ans. Ces animaux jouent un rôle important dans la chaîne alimentaire, et il semble que leur taux de mortalité naturelle soit élevé du fait du grand nombre de poissons prédateurs.

On a relevé des fluctuations naturelles régulières où irrégulières de la densité du stock (et des captures au chalut), provenant principalement de variations de la température de l'eau. L'afflux d'eaux chaudes de fond provenant du détroit de Davis contribue à transporter de grandes quantités de crevettes sur les fonds chalutables des fjords et d'autres zones côtières. L'arrivée d'eaux exceptionnellement froides peut détruire un stock local, comme cela s'est produit dans les fjords de la région d'Holsteinsborg durant l'hiver de 1949.

Les fluctuations relevées dans les captures au chalut proviennent surtout des variatons naturelles de la densité du stock, et la surexploitation ne paraît pas poser actuellement de problème au Groenland. Il convient toutefois d'éviter de pêcher des crevettes trop petites, et la mesure la plus efficace à cet effet consisterait à encourager le chalutage en eaux profondes, où prédominent les grosses crevettes, tandis que les petites se trouvent surtout sur les hauts-fonds.

Pandalus borealis EN AGUAS DE GROENLANDIA; SU PESQUERIA Y BIOLOGIA

Extracto

La pesquería del camarón Pandalus borealis en Groenlandia empezó en 1935, y desde la segunda Guerra Mundial se ha convertido en una industria muy importante que cuenta con fábricas en muchas ciudades.

Los camarones están ampliamente distribuidos en aguas de Groenlandia, en donde viven en fondos blandos a profundidades de 150 a 500 metros, principalmente, y a temperaturas de 1 a 2°C, sobre todo. Su desarrollo y crecimiento son relativamente lentos en comparación con las poblaciones de aguas más meridionales y más cálidas; el cambio de macho a hembra no se verifica hasta que tienen 4 ó 5 años. Desempeñan un importante papel en la cadena alimentaria y parece que sufren una gran mortalidad natural por la existencia de muchos predadores.

Se han observado fluctuaciones naturales, regulares e irregulares en la densidad de las poblaciones (y en las capturas realizadas al arrastre), causadas sobre todo por las variaciones en la temperatura del agua. La entrada de aguas templadas de fondo desde el estrecho de Davis ayuda a transportar grandes cantidades de camarones a las zonas donde se pesca al arrastre en los fiordos y en otros lugares próximos a la costa. Excepcionalmente el agua fría puede destruir poblaciones locales como ocurrió en los fiordos de Holsteinsborg en el invierno de 1949.

Las fluctuaciones de las capturas efectuadas al arrastre se deben, en su mayor parte, a variaciones naturales en la densidad de las poblaciones, y la pesca excesiva no parece que actualmente constituya un problema en Groenlandia. Sin embargo, conviene evitar la captura de camarones de poco tamaño, y para ello la medida más eficaz podría consistir en fomentar la pesca al arrastre en aguas profundas, en donde predominan los camarones grandes, mientras que los de tamaño pequeño son muy abundantes en aguas más superficiales.

1 SHORT HISTORY OF THE FISHERY

The TJALFE Expedition, 1908 to 1909, established the occurrence of deep-sea prawns (Pandalus borealis Krøyer) in Greenland waters, and when the landings of halibut for a canning factory in the town Holsteinsborg failed soon after 1930, attempts were made to fish prawns instead of halibut for canning. After some experiments in 1934 a commercial prawn fishery was started in 1935, and it continued with success until the second world war. After the war systematic investigations were carried out by Greenland Fisheries Investigations under the leadership of Dr. Paul Hansen, and in a few years the most important prawn grounds in West Greenland waters were found. Very rich grounds were found in Disko Bay (1 to 3 in Fig. 1), where a fishery was started in 1949, and in 1950 a fishery was started in the fjords at Narssaq (10 and 11 in Fig. 1). In the following years the fishery constantly increased, especially in the years since 1960 (Fig. 2). Many grounds are now exploited (Fig. 1), but by far the biggest quantities are landed at Disko Bay, as seen in Fig. 2.

The prawn fishery is carried out from small cutters (mostly 20 to 25 RGT), and the gear used is a fine meshed otter trawl (mesh size 20 to 22 mm from knot to knot in codend). The prawns are landed fresh at the factories, where they are boiled, peeled, and then either canned or frozen. On the map (Fig. 1) eight towns with factories are shown, and other smaller factories are established at three outposts. Six of the factories belong to the Royal Greenland Trading Company, and the others are private.

2 OCCURRENCE AND BIOLOGY

The deep-sea prawn is distributed along most of West Greenland and in the southern part of East Greenland. It lives on soft bottoms mainly at depths from 150 to 500 m, in all fjords and coastal waters with positive bottom temperatures (mostly 1 to 2°C), but in threshold fjords with cold bottom water (sub-zero) only a few small prawns are found, and P. borealis tends to be replaced by other prawn species, mostly Eualus macilentus.

In addition to the inshore waters of West Greenland, deep-sea prawns are also widely distributed and common in the deep parts of the Davis Strait. Since 1908, several Danish expeditions have made fishing experiments with fine meshed trawls in the Davis Strait, but the most numerous and extended were some prawn trawl experiments made by R/V DANA in July 1964 and 1966 in the deeps between the fishing banks and on the western slopes of the banks.

As the results of biological investigations have been published by Horsted and Smidt (1956, 1965) and by Smidt (1965), only the main features are given here, supplemented with results from more recent studies.

The Greenland deep-sea prawns are protandric hermaphrodites, as in other stocks, and they differ from the stocks in southern and warmer seas (e.g. the North Sea) in that no primary females have been observed in Greenland waters. Spawning takes place in July and August, and the females are ovigerous for about 9 mo until hatching takes place in April and May, while in Skagerak, for example, the ovigerous period lasts 5 mo. Development to mature male and female stages is also relatively slow in Greenland compared with more southern waters. In the Skagerak the prawns become males when 1½ yr old and females when 2½ yr old, while the Greenland prawns become males when 3 yr old and females when 4 or 5 yr old (Fig. 3). In the southwestern fjords with warm bottom water (normally over 1°C) sex change takes place when the prawns are 4 yr old, while in threshold fjords with colder water (under 1°C) and in Disko Bay, sex change takes place when they are 5 yr old. In some stocks some of the prawns change when 4 yr old and the remainder when 5 yr old.

Numerous trawling experiments over several years have shown that the small prawns predominate on shallower grounds, while big prawns are predominant at deeper water.

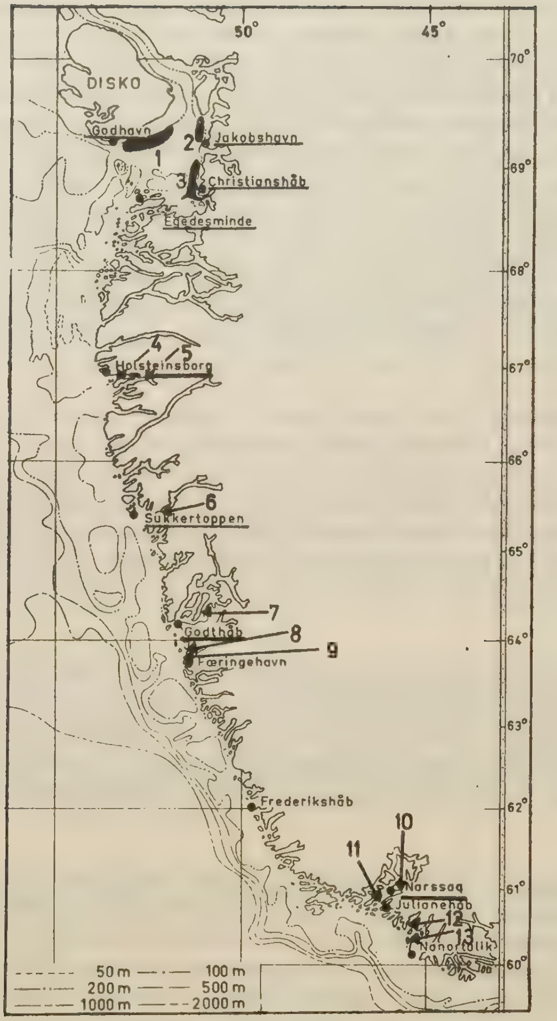
50°
45°
70°
69°
68°
67°
66°
65°
64°
63°
62°
61°
60°
DISKO
Godhavn
1
2
Jakobshavn
3
Christianshåb
Egedesminde
4
5
Holsteinsborg
6
Sukkertoppen
7
Godthåb
8
9
Færingehavn
Frederikshåb
10
11
Narssaq
Julianehåb
12
13
Nanortalik
50 m
100 m
200 m
500 m
1000 m
2000 m

Fig. 1 Exploited trawling grounds (Nos. 1-13) in West Greenland. Grounds in Disko Bay shown in extension, other grounds only by an arrow. Towns with prawn industries underlined.

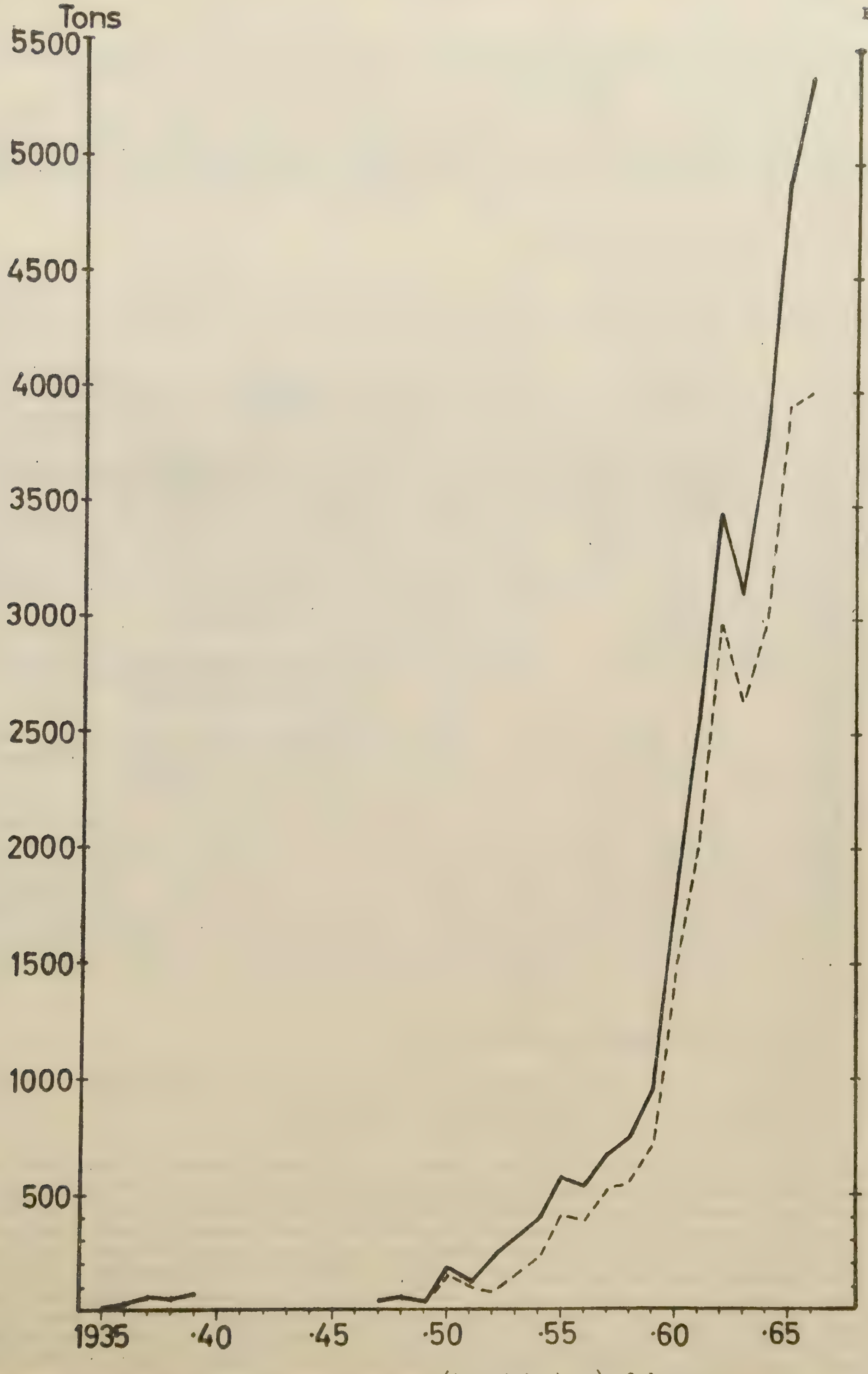

Fig. 2 Total annual landings (in metric tons) of deep-sea prawns in Greenland (full line) and annual landings from Disko Bay (broken line).

Observations made by Horsted (Horsted and Smidt, 1956:83-4; 1965:206) seem to show that the strength of year classes are of importance for the recruitment.

The deep-sea prawn must play an important role in the food chain. There seems to be a great natural mortality due to numerous predators, especially Greenland halibut (Reinhardtius hippoglossoides), halibut (Hippoglossus hippoglossus), cod (Gadus morhua), redfish (Sebastes marinus), several species of Lycodes, and other fish species (Smidt, 1965:101-2).

3 FLUCTUATIONS IN STOCK DENSITY

Fluctuations in the fishery due to fluctuations in the density of stocks have often been noticed, and in several cases it has been shown that variations in bottom temperatures were the cause of these fluctuations.

More or less regular variations in stock density, correlated with temperature variations, were observed by Horsted (Horsted and Smidt, 1956:79-82) in some fjords in the Julianehab district (10 and 11 in Fig. 1). Inflow of warm bottom water from the Davis Strait was followed by increasing trawl catches (kg/h trawled), and the migration of prawns was confirmed by tagging experiments.

The rich and extended prawn grounds found in 1964 by R/V DANA, in the Davis Strait, north of Store Hellefiske Bank, are regarded as an important recruitment reserve for the prawn grounds in Disko Bay. In July 1964, DANA trawled on average 180 kg of very big prawns per hour, mainly from depths of 400 to 500 m, but in 1966 it only got about 90 kg/h in the same area. It is remarkable that the commercial cutters in Disko Bay got unusually big catches of unusually big prawns in 1966, and that in the same year the deep-water temperatures were unusually high in the Davis Strait, in Disko Bay and in several fjords (see Fig. 4). It is therefore probable that large quantities of big prawns were transported into Disko Bay with the intrusion of warm bottom water from the Davis Strait.

In general, the extended resources of deep-sea prawns in the Davis Strait may thus be regarded as important reserves for the prawn stocks in West Greenland fjords and inshore waters, where the commercial fishery is carried out.

However, the circumstances are different in certain fjords where there is an effective sill or threshold, such as in the fjords at Holsteinsborg (4 and 5 in Fig. 1). A threshold effect caused winter cooled water to accumulate there during the extremely cold winter of 1948 to 1949 and totally killed the prawn stocks, and in the summer of 1949 unusually low bottom temperatures (-1.6°C) were recorded. After that catastrophe the threshold retarded the intrusion of prawns from Davis Strait, and it was 4 to 5 yr before the fjord stocks recovered. As seen from Fig. 4, the temperature conditions are much more unstable in the fjords at Holsteinsborg than in Disko Bay, but the events in 1949 must nevertheless be regarded as rather exceptional.

4 EXPLOITATION AND POSSIBLE PROTECTIVE MEASURES

The conclusion from section 3 must be that fluctuations in the Greenland prawn fishery are mainly due to uncontrollable natural variations in stock density, in most cases presumably caused by variations in water temperature.

This view is confirmed by the development of the prawn fishery in Disko Bay, where the annual landings have increased very much in recent years, as seen from Fig. 2. Therefore some investigations were made in 1963 and 1964 in order to see if the exploitation could be detected in the catches (quantity per hour trawled), but it was not possible to show any decline since the time when the prawn fields were practically virgin. Some catches made by the research cutter in 1964 are most instructive in this respect when compared with catches made by the same cutter in previous years (see Table I), and the exceptionally good catches of 1966 seem to confirm that there has been no decline in catch rates. The problem for the prawn industry at Disko Bay is not to get sufficient quantities of prawns landed but to process the prawns as fast as they are landed.

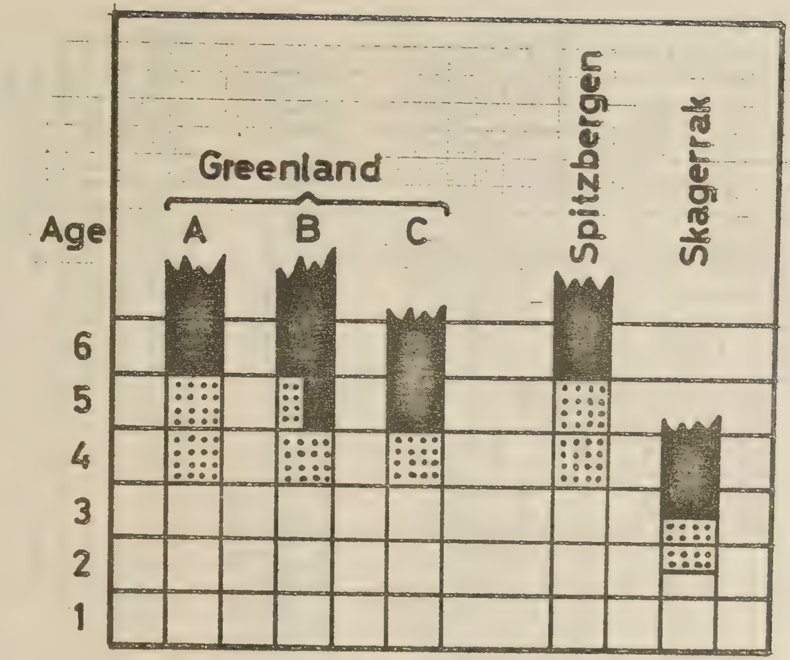

Fig. 3 Variations in development of deep-sea prawns at Greenland (A, B, C.) compared with other areas.

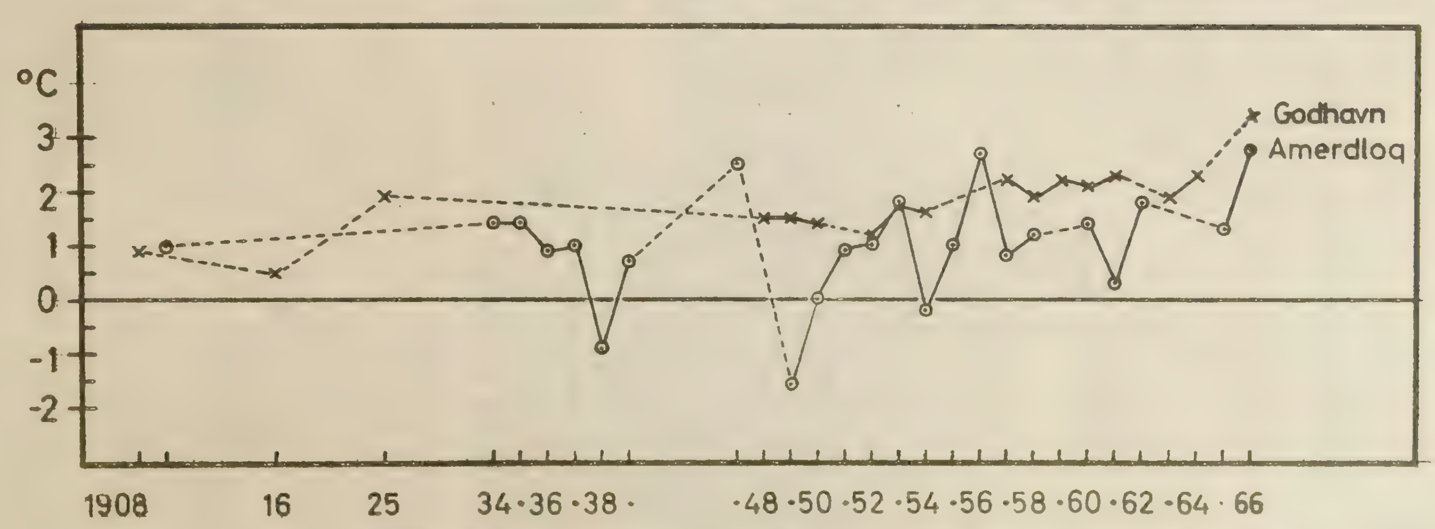

Fig. 4 Temperatures at 300 m depth in summer in different years on the Godhavn prawn grounds in Disko Bay (June-August), and in Amerdloq Fjord at Holsteinsborg (May-August). Broken lines join observations separated by two or more years.

TABLE I

Prawn catches (kg/h trawled) made by R/C ADOLF JENSEN in Disko Bay

		Prawn grounds		
		1.Godhavn	2.Jakobshavn	3.Christianshab
Virgin period	Years	1948-61	1947-61	1947-52
	No.hauls	17	16	8
	Av.catch (kg/h)	94	98	122
1964	No.hauls	4	2	12
	Av.catch (kg/h)	108	105	153

Even if there is no present problem of overfishing in the Greenland prawn fishery, a heavy exploitation of smaller, isolated fjord stocks or a crowding of the cutter fleet on single prawn grounds in Disko Bay may be felt for a short time. It may therefore be of some importance to be able to protect the undersized prawns. Also from the point of view of the industry it is desirable to avoid the undersized prawns. In order to find suitable measures to avoid or protect the undersized prawns, some fishing experiments with different mesh sizes in the trawl were made in Disko Bay in 1963 and 1964 on all three prawn grounds.

In six experiments a mesh size of 20 mm (from knot to knot) was used, in three experiments 24 mm mesh size, and in five experiments 28 mm mesh size. The results were that during the time 100 kg of prawns were fished by nets with 20 mm meshes, 67 kg were fished with 24 mm meshes, and only 29 kg with 28 mm meshes.

The selectivity of the different mesh sizes is shown in Table II, where prawns over 6 g (mostly suitable for hand peeling), from 3 to 6 g (mostly machine peeled), and under 3 g (discarded) are separated in percentages by weight. It is seen that 28 mm meshes avoid practically all undersized prawns, but the catches are so small that this mesh size must be regarded as unsuitable. Also 24 mm meshes give much reduced catches compared with 20 mm meshes without giving noticeably better protection of the undersized prawns. Therefore 20 to 22 mm meshes, which are the mesh sizes actually used by the Greenland fishermen, must be regarded as appropriate. The results are also clearly seen from Fig. 5.

TABLE II

Selectivity on prawns by different mesh sizes.
The size groups given in percentages by weight

Various size groups of prawns	Mesh sizes in mm		
	20	24	28
over 6 g	68 %	75 %	89 %
3-6 g	26 "	20 "	10 "
under 3 g	6 "	5 "	1 "

Instead of increasing the mesh sizes, the best way to avoid the undersized prawns would be to trawl the prawns at greater depths, where the bigger prawns predominate, while the smaller prawns are most numerous at shallower depths. In Disko Bay, the most appropriate trawling depths are 320 to 400 m.

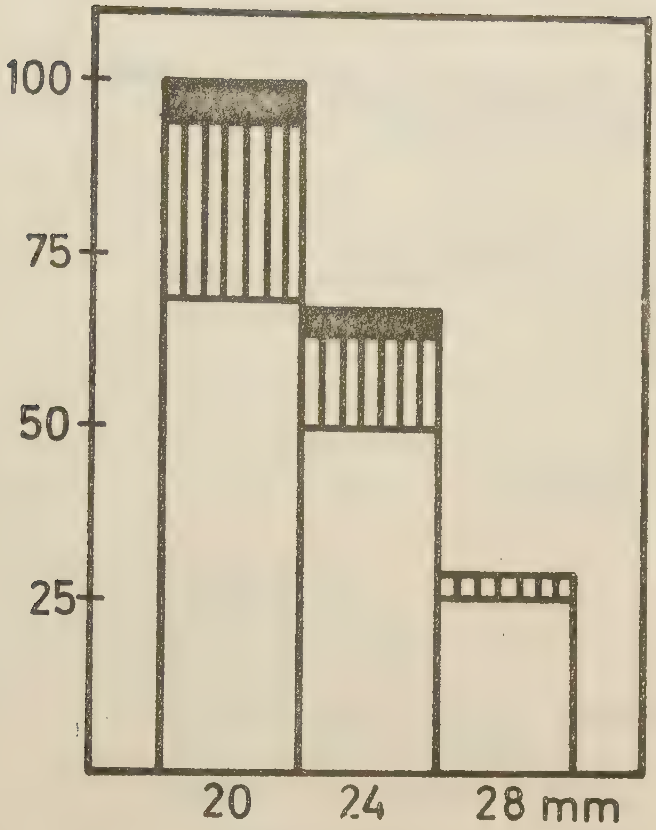

Fig. 5 Relative variations (by weight) in prawn catches from Disko Bay by various mesh sizes (20, 24 and 28 mm from knot to knot) in the trawl cod-end. White sections of columns indicate prawns over 6 g, striped sections indicate prawns between 3 and 6 g, and black sections indicate undersized prawns (under 3 g).

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Smidt, E., 1965 Deep-sea prawns and the prawn fishery in Greenland waters. Rapp.P.-v.Réun. Cons.perm.int.Explor.Mer, 156(6):100-4

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THE COMMERCIAL PRAWN *Macrobrachium malcolmsonii* (H. MILNE EDWARDS) OF THE RIVER GODAVARY, A DISCUSSION ON THE TREND AND CHARACTERISTICS OF THE POPULATION DURING 1963-1966

by

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Abstract

Macrobrachium malcolmsonii is the only freshwater prawn of commercial importance in the River Godavary. Its annual yield of about 80 tons makes up about 30 percent of the landings of fish and prawns from the river.

The population studied is isolated from the rest of the river for seven months in each year by barriers across the river in two regions 189 km apart. Methods of survey, trends in prawn yields, and catch/effort relationships are discussed. Methods of data collection and computation and their shortcomings are examined. Statistics of production are utilized to assess indices of population density and for a preliminary appraisal of population characteristics.

The area is divided into two sub-areas and the commercial population is confined to one of these from January to June. Breeding lasts from July to October with two peaks. The variable pattern of floods has some effect on the survival of larvae. An interesting juvenile mass movement occurs from October to January. Intense harvesting of these juveniles and factors affecting the survival of larvae are postulated as two of the reasons contributing to fluctuations in total yields.

E/51

LA CREVETTE Macrobrachium malcolmsonii (H. MILNE EDWARDS) DE LA GODAVARI ETUDE SUR L'EVOLUTION ET LES CARACTERISTIQUES DE LA POPULATION EN 1963-66

Résumé

Dans la Godavari, Macrobrachium malcolmsonii est l'unique crevette d'eau douce revêtant une importance commerciale. Son rendement annuel est d'environ 80 tonnes et représente approximativement 30 pour cent des apports de poissons et de crevettes de ce fleuve.

La population étudiée est isolée du reste du fleuve pendant sept mois chaque année au moyen de barrières installées en travers du cours d'eau dans deux régions distantes de 189 km. Les auteurs examinent les méthodes d'étude, l'évolution des rendements en crevettes, et les rapports capture/effort de pêche. Ils étudient les méthodes de rassemblement et de calcul des données, ainsi que leurs inconvénients. Les statistiques de la production servent à déterminer les indices de densité de la population et à évaluer à titre préliminaire les caractéristiques de celle-ci.

La région est divisée en deux zones, la population "commerciale" étant confinée dans l'une de celles-ci du mois de janvier au mois de juin. La période de reproduction s'étend de juillet à octobre, avec deux pointes d'activité maximale. Le régime variable des inondations influe quelque peu sur la survie des larves. Une intéressante migration massive de jeunes s'observe d'octobre à janvier. Selon les auteurs, l'intensité de la pêche de ces stades juvéniles et l'effet des facteurs qui influent sur la survie des larves sont deux des raisons qui expliquent les variations du rendement total.

LA POBLACION COMERCIAL DE LANGOSTINOS Macrobrachium malcolmsonii (H. MILNE EDWARDS) DEL RIO GODAVARY EXAMEN DE LAS TENDENCIAS Y CARACTERISTICAS DE LA PRODUCCION DURANTE 1963-66

Extracto

Macrobrachium malcolmsonii es el único langostino de agua dulce de importancia comercial en el río Godavary. Su rendimiento anual que es de unas 80 toneladas constituye el 30%, aproximadamente, de los desembarques de pescado y langostinos obtenidos en el río.

La población estudiada es aislada del resto del río durante siete meses al año con barreras que cruzan el río en dos regiones separadas por 189 km. Se analizan los métodos de reconocimiento, las tendencias de los rendimientos de langostinos, y las relaciones captura/esfuerzo. Se examinan los métodos de recogida y computación de datos y sus defectos. Las estadísticas de producción se emplean para determinar los índices de densidad de la población y para realizar evaluaciones preliminares de las características de las poblaciones.

La zona se divide en dos subzonas y la población comercial se limita a una de éstas desde enero a junio. La cría dura desde julio a octubre con dos puntos máximos. La variabilidad de las inundaciones tiene algunos efectos en la supervivencia de las larvas. De octubre a enero tiene lugar un interesante movimiento en masa de las formas juveniles. Se sugieren como dos de las razones que contribuyen a las fluctuaciones de los rendimientos totales, la intensa recolección de ejemplares en fase juvenil y los factores que influyen en la supervivencia de las larvas.

1 INTRODUCTION

The Godavari is one of the famous rivers rising in the Western Ghats of India, running through the Deccan plateau and entering the Bay of Bengal, in Andhra Pradesh. It is never completely dry.

The freshwater prawn fishery has been studied in a stretch of the river 189 km in length. It is a single species fishery which contributes more than any other fish or prawn to the total landings from this stretch and averages about 30 percent of the total catch. The annual yield fluctuates around 80 tons, and in 1964 it reached a maximum of 110 tons. Estimates from markets show the prawn landings to yield increasing gross receipts through the years.

In this fishery migrating juvenile prawns of 10 to 20 mm are harvested in large quantities for sale as dry or fresh prawns. In recent years there have been some experimental attempts to transplant juveniles for growth in reservoirs, ponds and fish farms. There is every reason to assume that both these factors have great repercussions on the adult commercial fishery which shows high fluctuations each year.

Any management programme envisages detailed studies of reactions of populations to different exploitation levels. These, along with the studies on yield and its prediction, require detailed catch/effort statistics. A survey and sampling programme was initiated during the year 1963, which formed part of the programme of investigation on the commercial fisheries of the River Godavary. The present paper deals with the annual trends in prawn production, detailed statistics of the effort and yield, and trends in the yield in the different fishing grounds during the four years of study (1963 to 1966). Commercial statistics are used to study the characteristics of the population.

2 THE PRAWN FISHERY

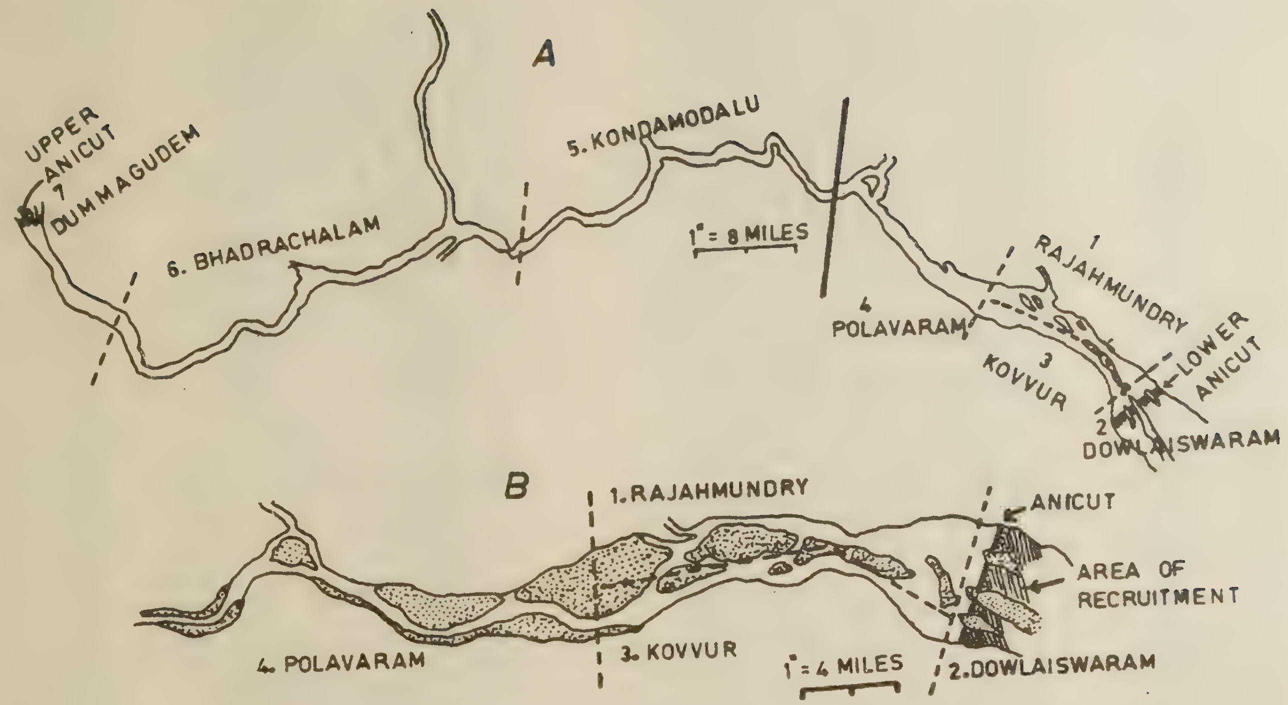
2.1 Exploited species

Two members of the subfamily Palaemoninae are normally present in the freshwater zone of the river, but only *Macrobrachium malcolmsonii* (H. Milne Edwards) is important in the fishery. The other species is *M. scabriculum* (Heller) which contributes less than 0.01 percent of the yield. In times of flood, the small prawn *M. lamarrei* (H. Milne Edwards) occasionally gets access to the river from adjacent ponds and canals. *M. malcolmsonii* is fished from the upper tidal reaches of the river along almost its entire length. Ibrahim (1962) recorded that the commercial exploitation extended 800 km upstream of the Rajahmundry township but is mainly confined to (i) Rajahmundry (in the State of Andhra Pradesh) at a distance of 80 km from the sea, (ii) Sironcha (in the State of Maharashtra) 450 km from the sea and (iii) Nanded (also in Maharashtra) 800 km from the sea.

2.2 Region

The investigations were carried out in the first of the three areas detailed above. This region is a navigable length of 189 km; it is barred both at its upper and lower regions by anicuts (Fig. 1) which isolate it for about seven months in each year, from November to June. Downstream, about 20 km from the lower anicut, is the upper tidal limit of the estuary of the river. The prawn population here is limited by the salinity. Upstream beyond the upper anicut, the population is very sparse for about 250 km and then becomes once more concentrated near the townships of Sironcha and Nanded.

The months July to October comprise the flood period of the river. Fishing from boats is suspended during this period, and castnets and other minor gear are operated from the shore during periods of recession of the floods. This flood season is also the main breeding season of the prawn population.


A
UPPER ANICUT
7
DUMMAGUDEM
6. BHADRACHALAM
5. KONDAMODALU
1" = 8 MILES
4
POLAVARAM
1
RAJAHMUNDRY
3
KOVVUR
LOWER ANICUT
2
DOWLAISWARAM
B
1. RAJAHMUNDRY
ANICUT
AREA OF RECRUITMENT
4. POLAVARAM
3. KOVVUR
1" = 4 MILES
2. DOWLAISWARAM

SUB-AREA: I (18860 Ha)

	a.h	a.w.f
1.	8495	0.4504
2.	380	0.0201
3.	6385	0.3385
4.	3600	0.1908

SUB-AREA: II (16600 Ha)

	a.h	a.w.f.
5.	3080	0.1855
6.	5345	0.3219
7.	8175	0.4924

Fig. 1 (A) Map of River Godavary showing the area of investigation. Thick line across the river indicates division into sub-area I and sub-area II. The sand bars in the river are deleted from the figure. Numbers 1 to 7 are the sub-sub-areas. a.h.: area in hectares; a.w.f.: areal weighting factor.

(b) Enlarged figure of sub-area I showing details of the sub-area structure.

During the season of its commercial exploitation, from December to June, the population is confined between the two anicuts. Some recruitment from outside this region takes place from October to December when juveniles of 10 to 30 mm move up the lower anicut (Ibrahim, 1962). The anicuts prevent any emigration of larger prawns during this period. During the period of commercial exploitation, the population is self-contained, with its own recruitment sources. Tagging on a large scale should clarify the migrations of the species, showing whether the populations beyond and between the anicuts mix, and, if so, to what extent.

2.3 Review of life-history

Along the entire river stretch, maturation, spawning, fertilization and hatching of eggs all occur in fresh water, in the monsoon flood season. The breeding period extends from the end of June to the beginning of October, when the river is in full flood. At least two waves of larvae are released. The larvae are probably carried down river along with the flood-waters, when the waters below the lower anicut and even in the tidal limits are inundated with fresh water. The larvae probably grow here, and by October, when the last breeding is still taking place, they commence to return. Young prawns of 8 to 30 mm continue to re-enter the freshwater environment from October to January or February. It is not known at present whether the juveniles which move up the lower anicuts are the only source of recruitment. These juveniles suffer high mortality at the anicuts from intense harvesting and heavy predation by birds, and if they are the only source of recruitment, this mortality is likely to affect adversely the total stocks to a very great extent.

The average life span of the species is judged to be about 3 to 3½ yr in females and 4 to 4½ yr in males.

2.4 Types of fishery

All stages from small juveniles to the largest adults are fished heavily, and there are no fishery regulations on closed seasons or minimum sizes. The entire harvest is utilized for human consumption.

The commercial fishery is conducted by a number of professional fishermen operating combined units of shore seines with dragnets (jaruguvala), independant dragnets (kontevala), and castnets. The main gear used is the jaruguvala and the catch of this gear averages about 60 percent prawns and 40 percent fish (Fig. 2). About 70 percent of the total landings of prawn for the total area is landed by jaruguvala and 30 percent by miscellaneous minor gear. In the main fishing ground (sub-area I) 75 percent of prawn is landed by jaruguvala, and 25 percent by miscellaneous gear. In the sub-area II, jaruguvala is very rarely operated and the castnet is the only gear catching prawns, accounting for 75 percent of the landing of prawn of this sub-area. In the present paper estimates of the prawn population of the river, and of landings, trends and population indices are based on catches with jaruguvala. The castnet is not at all comparable to jaruguvala and no attempt is made to compare catches from the two nets.

2.5 Boats and gear

The boat used in jaruguvala operation is an ordinary country boat, 10 m long and of 3 ton capacity, manoeuverable by one man. Each jaruguvala unit is composed of 14 to 20 pieces, each piece of length 20 m, height 3 m, and with a uniform body mesh of 3.0 cm (note: the mesh is never absolutely uniform; a variation of 0.5 cm is quite common in these hand-woven nets). Along the bottom, the net is folded back for about 20 cm to form a pocket, and along this folded edge several beads (of burnt clay) are knotted at intervals of 5 to 8 cm. While in operation, one end of the net is left on shore and the remaining net is taken on the boat and payed out in a wide semi-circle before bringing the other end to shore (Fig. 3). The 'shore' can be any sand bank in the middle of the river or it may be the actual bank of the river. A float is attached to the middle of the net, which may be in water of 10 to 15 m before hauling commences.

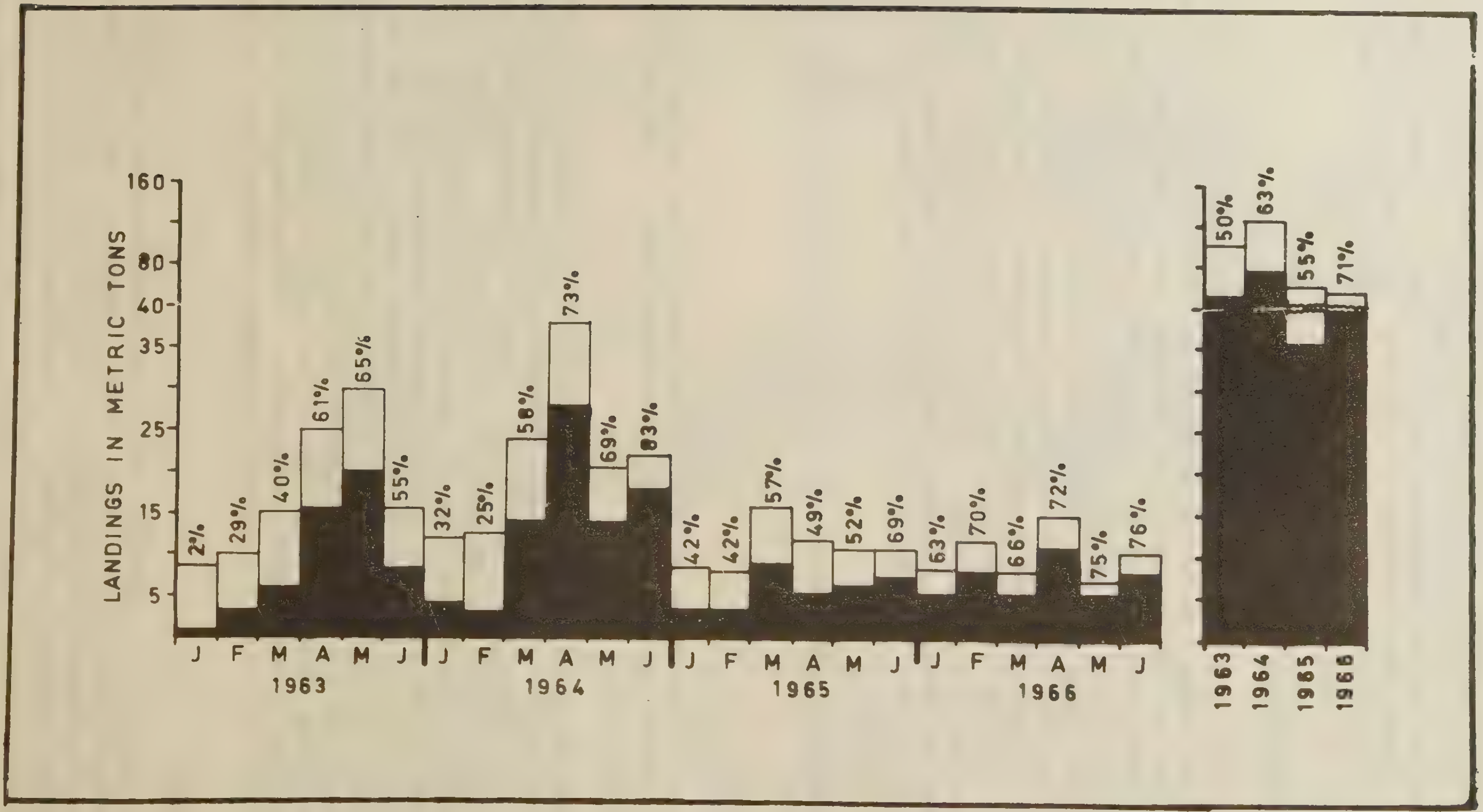


Fig. 2 Histogram depicting percentage composition of prawn (shown in black) in the total landings by jaruguvala in the sub-area I and season I, viz. January to June, in each year.

At the end of these operations, 4 to 6 men at each end commence dragging the net slowly in. After three quarters of the net is dragged on to the shore and the outer part is in rather more than 1 m of water, all the men except one at each end leave the main net and take up dragnets (mesh 1 cm, length 20 m, and height 1½ m). They surround the main net by spreading out in a semi-circle behind it (Fig. 4), then the dragnets are pulled along the bottom towards the shore, while the two men at each end of the jaruguvala pull it in simultaneously. All the 'escape' from the jaruguvala is thus caught in the dragnets. Each haul may last from 45 min to 3 h.

Routine jaruguvala operation is to fish the nets any time from 04:00 to 08:00 h, from 10:00 to 12:00 h or from 12:00 to 15:00 h. Fishing is never carried out between midnight and 04:00 h. The landing time usually corresponds to the market timings which are between 08:00 and 10:00 h and between 16:30 and 18:00 h.

The castnet is very common along the entire stretch of the river. It is operated by one man, mainly from the shore but sometimes from a boat. The castnet fisherman often uses lure or bait in the form of food balls (rice-bran + rice). Castnet fishing may be carried out at any time of the day or night.

2.6 Commercial fishery statistics

Statistics of net operation and prawn yield in the entire stretch were not maintained prior to 1963. The first attempt at a statistical survey of the riverine fishing areas and gear was made in 1959, and thereafter survey and inventory checks have been made at intervals of three to four years. Such checks were made in 1962 and again in 1965 to assess the changing distribution of gear along the river stretch.

2.6.1 Survey design In this type of riverine fishery, there is very little or no subsistence fishery. The survey design is as follows:

Survey assistants collect data on gear, landings, size-composition of landings (excepting those of prawn), area of net operation, duration of net operation and other relevant facts; they visit eleven fish landing centres at regular intervals. Each assistant covers approximately 60 km of river. These data are assembled in a proforma and passed on for further processing. The entire fishing area is marked off into sub-area I and sub-area II based on the location and distribution of jaruguvala effort. Sub-area I is the main commercial prawn fishing region exploited by this gear and the annual catch averages more than 10 times that of sub-area II (Table I). This sub-area is further divided into four sub-sub-areas viz: Rajahmundry, Dowlaishwaram, Kovvur and Polavaram, delineated in Fig. 1. The same figure shows the total area in hectares and the areal weighting factor of each sub-sub-area. Sub-area II is divided into three sub-sub-areas, Bhadrachalam, Dummagudem and Kondamodalu; it is fished by castnet in all seasons, but landings are small.

2.6.2 Season Important seasonal differences in the fishery are confined to sub-area I. The main prawn fishing season (season I) commences in December of each year when one jaruguvala unit is put into operation. By January more units enter the fishery. Maximum effort and catch have usually been recorded for the months of April or May and sometimes in June. If the floods are delayed, one or two fishing units continue their operations till July. By mid-July, however, all jaruguvala operations cease. From July to December (season II) intermittent fishing by castnet takes place.

In the sub-area II, there is little difference in yield between the two seasons.

2.6.3 Effort and its distribution The effort is recorded by sampling at actual fishing areas. Landing sites are visited for two days in succession in a week, and information is also obtained from net owners. The regional distribution of various gear is facilitated by the division of the river stretch into various sub-sub-areas, as explained above.

The quantity of effort expended is calculated by estimating the number of times the units have operated multiplied by the average man-hours expended by each net unit.

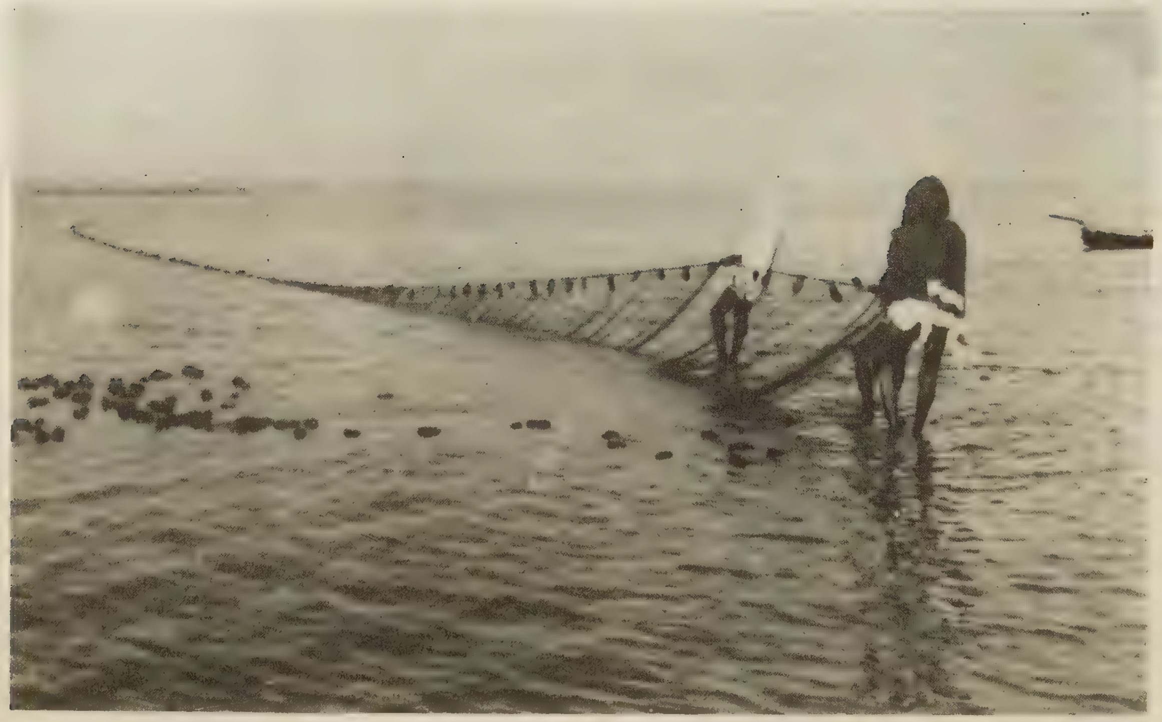


Fig. 3 Jaruguvala operation in the river: first stage when shore seine is paid out.

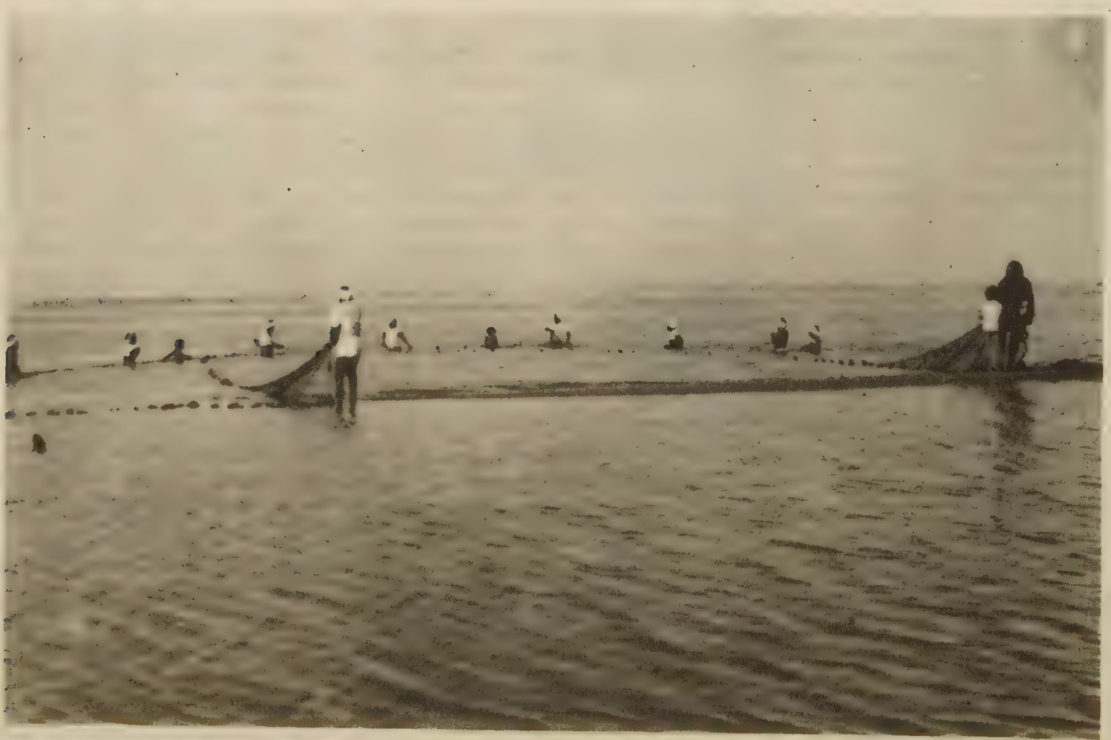


Fig. 4 Second stage of the jaruguvala operation. Main net at a distance of about 10 m from shore with drag-net (kontevala) spread out behind it. Fishermen at intervals, pressing net down and slowly dragging it towards shore.

TABLE I

Prawn catch in tons, taken by different gear in sub-area I and sub-area II
Season I, January to June; Season II, July to December

Year		Sub-area I, season I			Sub-area I, season II			Total sub-area I	Total sub-area II			Total sub-area I and sub-area II
		Jaruguvala	Other gear	Total	Cast-net	Other gear	Total		Cast-net	Other gear	Total	
1963	Yield	52.9	17.1	70.0	2.9	5.9	8.8	78.8	7.7	4.3	12.0	90.8
	%	75.5	24.3		32.3	67.5			63.9	35.9		
1964	Yield	81.3	20.2	101.5	2.1	0.6	2.7	104.2	4.6	0.9	5.5	109.7
	%	80.0	19.8		78.1	21.9			83.1	16.9		
1965	Yield	36.4	13.6	50.0	3.5	1.5	5.0	55.0	4.9	0.9	5.8	60.8
	%	72.7	27.2		69.0	31.0			84.2	15.8		
1966	Yield	43.6	12.8	56.4	2.8	7.5	10.3	66.7	4.4	0.5	4.9	71.6
	%	77.3	22.7		27.6	72.4			89.2	10.8		
Total	Yield	214.2	63.7	277.9	11.3	15.5	26.8	304.7	21.6	6.6	28.2	332.9
	%	77.0	22.8		42.0	58.0			76.2	23.6		

2.6.4 Landings Another important variable is the catch. The statistics of catch are obtained by sampling once a week at the fish landing centres. The direct landing of catches immediately after fishing facilitates recording precise weights of prawn landing. A major shortcoming in sampling is the difficulty of recording the size-composition of the landings.

Since the commercial utilization of prawn is only for human consumption and no other non-commercial fishery has been noticed in the area of study, it can be said that the sampling adequately covers the total prawn harvest of this region.

Prawn landing statistics are of 'whole' weights, and the practice of removing 'heads' is not seen anywhere in riverine prawn fisheries. The catches are consumed locally, in a fresh condition.

3 FISHING EFFORT AND TOTAL PRAWN YIELD DURING 1963-1966 IN SUB-AREA I

Total seasonal fishing effort in sub-area I by jaruguvala (Fig. 5) during the years 1963 to 1966 averaged 252.5 thousand man-hours, and was comparatively less in the years 1963 and 1966 than in 1964 and 1965 (Table II). Total prawn landings for sub-area I in season I fluctuated between 36 and 81 tons in different years.

TABLE II

Jaruguvala effort and deviation from mean in sub-area I, season I

Year	In thousands of man-hours	% deviation from the mean
1963	244	- 3.3
1964	279	+ 10.5
1965	274	+ 8.5
1966	213	- 15.7
	Total 1,010	
	Mean 252.5	

Effort and catch data (Table III and Fig. 5) show the following trends. The sub-sub-areas Rajahmundry, Dowlaishwaram, Kovvur and Polavaram, in that order, ranked as top prawn producers. The distribution of effort within each sub-sub-area varied to a certain extent from month to month in each year. In Dowlaishwaram the effort was concentrated generally in the months of March to June. Nevertheless prawn fishing seems to have been entirely suspended in May and June 1966. These minor distributional differences, however, have not affected the total seasonal effort to any great extent except in 1966. Similar changes affected the catch also.

In Rajahmundry sub-sub-area, the greatest yield was taken in April, May or June in each year.

At Kovvur, during 1963 and 1964, no effort was expended from January to April. During 1965 and 1966, effort appeared to have shifted to this sub-sub-area from other regions, resulting in fishing operations from January onward.

At Polavaram, fishing usually commenced by late January and early February and varied considerably in intensity and yield.

TABLE III

Monthly estimated effort in man-hours (E) and catches (C) in kg by jaruguvala in each sub-sub-area in sub-area I for season I

Sub-area and year		January	February	March	April	May	June	Total
I. Dowlaishwaram								
1963	E	2,176	..	6,916	1,760	4,800	3,692	19,344
	C	189	..	419	357	498	510	1,973
1964	E	2,160	..	4,200	1,920	3,402	3,600	15,282
	C	206	..	564	204	623	395	1,992
1965	E	7,410	1,531	5,400	3,680	1,680	1,080	20,781
	C	531	291	643	521	83	53	2,122
1966	E	..	1,440	2,610	2,475	..	..	6,525
	C	..	257	631	457	..	..	1,345
II. Rajahmundry								
1963	E	..	3,600	9,480	11,200	14,880	5,390	44,550
	C	..	2,908	1,245	4,060	5,018	1,920	15,151
1964	E	6,720	6,480	11,392	11,914	11,700	8,240	56,446
	C	926	824	3,730	7,455	3,119	4,702	20,756
1965	E	4,632	6,178	9,231	4,530	7,905	5,400	37,876
	C	469	696	1,698	2,424	1,601	1,847	8,735
1966	E	4,620	6,806	5,640	9,052	4,953	7,560	38,631
	C	2,330	2,185	1,298	3,286	1,887	2,814	13,800
III. Kovvur								
1963	E	..	750	..	..	1,395	..	2,145
	C	..	50	..	..	83	..	133
1964	E	..	..	..	345	2,304	540	3,189
	C	..	..	..	98	87	93	278
1965	E	..	..	6,293	4,625	2,400	1,860	15,178
	C	..	..	156	856	205	153	1,370
1966	E	2,160	1,968	3,388	2,112	1,050	760	11,438
	C	60	634	298	430	189	206	1,817
IV. Polavaram								
1963	E	..	2,400	1,176	3,540	3,660	1,800	12,576
	C	..	92	27	61	199	82	461
1964	E	..	2,160	4,140	4,800	3,150	2,660	16,910
	C	..	213	791	911	749	340	3,004
1965	E	..	2,100	2,490	4,380	3,600	3,285	15,855
	C	..	150	254	800	370	238	1,812
1966	E	1,152	5,280	3,680	1,920	1,200	1,440	14,672
	C	233	988	499	459	416	216	2,811

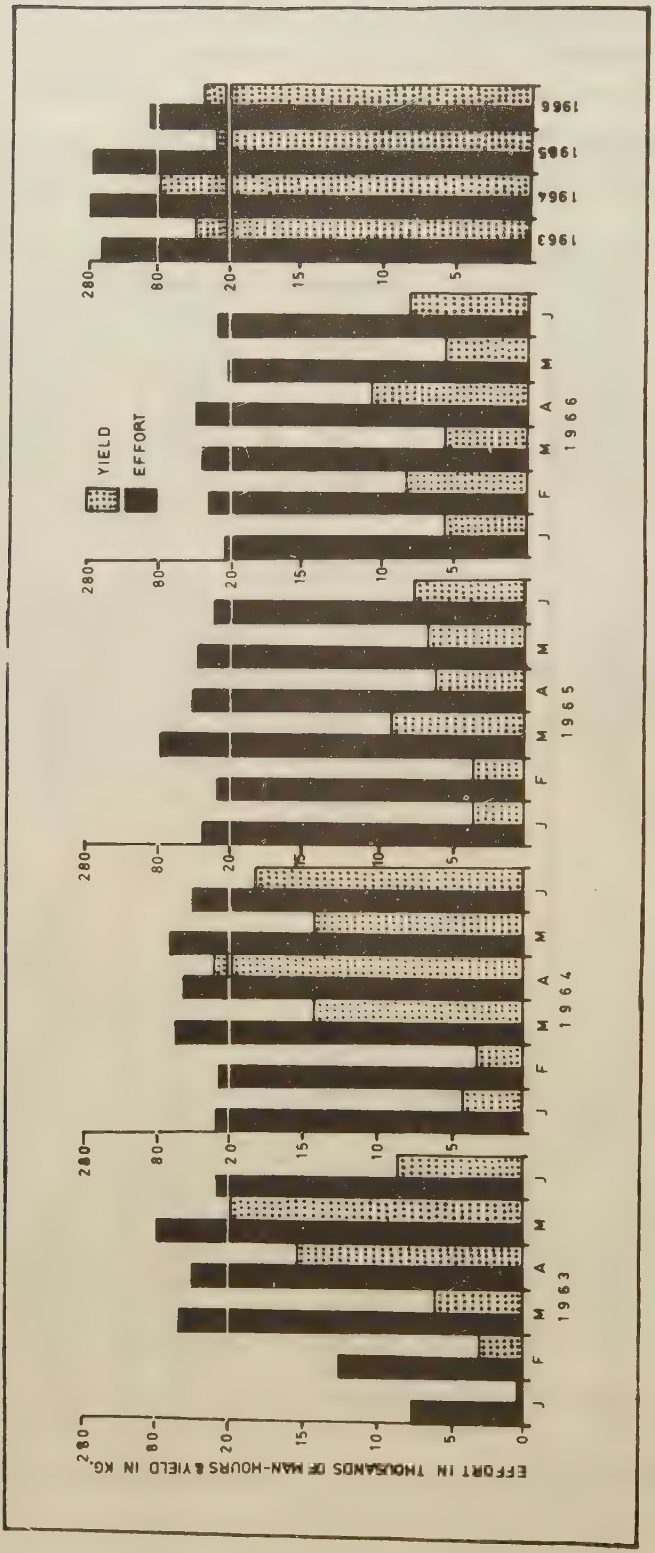


Fig. 5 Histogram showing effort expenditure and total commercial yield by jaruguvala in sub-area I and in season I (January to June).

4 METHODS OF POPULATION APPRAISAL

To study reaction of population to varying exploitation, suitable indices of population size must be obtained.

4.1 Fishable biomass index

Kutkuhn (1962) has defined the fishable biomass "as that fraction (in terms of weight) of a commercial population, which comprises those individuals vulnerable to capture with the gear commonly used by fishery". The fishable population in the present instance refers to that above the lower limit retained by the jaruguvala with the 'constant' mesh used in the gear. This lower limit is 50 mm. No selection practices are followed for the size-groups taken, and there is no discarding of prawns of any size at fishing or landing sites.

The geographical limits of the present population are known (between the two anicuts at Dowlaishwaram and Dummagudem for 6 to 7 mo in a year) and the manner in which effort is deployed over this is also known from sampling of commercial gear at regular intervals. Kutkuhn (1962) mentioned that, if these two factors are known, an index to the true probability with which a standard unit of the fishable biomass will have been removed can be derived for each time increment. Weighted averages of all fishing intensities calculated for each sub-area within the range of population is the "effective overall fishing intensity" ($\tilde{f}$) (Beverton and Holt, 1957; Kutkuhn, 1962). Gulland (1955, 1956) used a similar method to obtain biomass indices.

The fishing effort per unit area is the fishing intensity in a sub-area; the weighting factors are corresponding biomass indices of the sub-areas. "Since the ratio between catch (in weight) and effective overall fishing intensity is proportional to the fishable biomass, it follows that the fishing intensity is also proportional to the fishing mortality parameter, an important consideration in attempts to evaluate the latter" (Kutkuhn, 1962).

There are a few shortcomings in estimates which are associated mainly with the compilation of data by different persons. With experience this has been partly removed. Other bias comes from lack of uniformity of gear and conditions, which naturally results in variable catches, clogging of nets by algal masses, saturation of gear by miscellaneous fish, and patchy distribution.

The assumptions in regard to the operation and natural factors are:

i) that the water spread, from which the areal weighting factor is calculated, remained constant from year to year;

ii) that the effects of different operational abilities of men partaking in seining and the gear efficiency remained relatively constant; and

iii) that the dimensions of sampling error and bias, if any, remained constant for each time interval.

4.2 Computation

To show the method of computation, statistics of a sub-area are shown in Table IV, wherein commercial effort and *M. malcolmsonii* catches of one month (of May 1964) for each of the four unequal sub-sub-areas comprising sub-area I are included.

TABLE IV

Commercial statistics of prawn fishery in
sub-area I of the River Godavary, May, 1964

Statistical sub-sub-area	Area (ha) a_i	Areal weighting factor w_i	Total effort (man-hours) g_i	Total catch (kg) y_i	$\frac{\text{Total catch}}{\text{Total effort}}$ d_i
Dowlaishwaram	380	0.0201	162	46.70	0.2882
Rajahmundry	8,495	0.4504	1,172	576.27	0.4916
Kovvur	6,385	0.3385	72	14.53	0.2018
Polavaram	3,600	0.1908	450	67.06	0.1490
Area totals	18,860	0.9988	1,856	704.56	0.3796
	$\sum w_i \; d_i = 0.329$ = fishable biomass index for May, 1964				

Kutkuhn (1962) mentioned that if it is assumed that the biomass as manifested by the ratio of catch to effort (d_i) was constant within each of the i sub-sub-areas throughout the period indicated, then the best index of overall population biomass is the weighted mean catch-effort ratio for each sub-sub-area. Hence, the areal weighting factor (w_i), is the proportion of the total occupied area represented by the i^{th} sub-sub-area. The concepts of Gulland (1955, 1956), Beverton and Holt (1957), as given by Kutkuhn (1962) is shown in the notation:

$$\frac{\sum_i Yi}{\tilde{f}} = \frac{\sum_i Yi}{\dfrac{\sum_i fi\left(\dfrac{Yi}{fi}\right)}{\sum_i \dfrac{Yi}{fi}}} = \frac{\sum_i Yi}{\dfrac{\sum_i Yi}{\sum_i \dfrac{Yi}{fi}}} = \sum_i \frac{Yi}{f_i} = \frac{\sum_i a_i \dfrac{Yi}{gi}}{\sum_i a_i} = \frac{\sum_i a_i \; d_i}{\sum_i a_i} = \sum_i w_i \; d_i$$

where $f_i = g_i/a_i$ is the fishing intensity in the i^{th} the sub-sub-area:

Yi/fi is the index of fishable biomass in i^{th} sub-sub-area and other notations are shown in Table IV.

The $\sum_i w_i \; d_i$ is also known as "catch per unit effective fishing intensity". This is to distinguish it from "simple catch per unit fishing effort" or catch-per-man-hour in the present case, which would be obtained if the effort and catch statistics were not available on a sub-area basis; then the biomass would be assumed to be uniformly distributed throughout the area of commercial fishing operations. This would also result in an overall population figure which would be much higher. If the catch/effort ratio is used as biomass index, the great differences between successive time intervals could as well be due to changes in effort distribution as to real changes in population biomass.

5 POPULATION TRENDS AND CHARACTERISTICS

Over the period 1963 to 1966, annual M. malcolmsonii production by all gear, in the entire area of investigation fluctuated around an average of 80 tons, thus representing about 30 percent of the total production of the region of all species of fish and prawns. These high fluctuations in landings shown in Table I indicate that there might be actual changes in the population structure from year to year.

The yield histograms drawn from monthly landings (Fig. 5) reveal that the peak production in the entire region was attained during the first half of each year, 90 percent of each calendar year's catch being made in that period. This pattern of seasonal concentration was common in both the sub-areas, I and II.

The length-frequency distribution of the population shows that the prawns assembling in late winter to early summer are comparatively large. As the season progresses through May and June smaller size-groups, recruits from the previous year's breeding, become dominant in the commercial fishery. The survivors of this group in July to September constitute the spawning population; the gonads mature during May and June, and the first berried females appear in early July. In July, the commercial seine fishery closes owing to the commencement of the floods in the river, and any further fishing is carried out only by cast-nets. There is therefore little commercial exploitation of the spawning population.

This spawning population has at least two heightened periods of spawning activity, during July and September, and produces at least two main broods and a number of minor broods during the protracted breeding period, from July to September or October.

Excessive harvesting of small prawns naturally reduces the yield of larger sizes. Unfortunately, calculation of the biomass of each brood or by size was impossible. This also precluded the study of the effect of varying fishing intensities on different growth stages. Ibrahim (1962) recorded the percentage distribution of each year class in the fishery as: 0 and 1-year class (up to 80 mm total length) 82 percent, 2-year class 16.5 percent and 3-year class 1.2 percent, amongst females; and 0 and 1-year class 85.2 percent, 2-year class 14.5 percent and 3-year class 1.4 percent, in males. Thus the bulk of the catch during 1960 and 1962 consisted of 0 and 1-year class. With slight variations in the percentage composition, this can be taken as the general trend of the age-group composition in the years 1963 to 1966 also.

5.1 Sub-area I

5.1.1 Season I

5.1.1.1 Yield and population characteristics: Through the years 1963 to 1966, the prawn yield in this sub-area and season averaged 83.4 percent of total prawn yield of the river. Jaruguvala landings for each year are given in Table I, and landings for each of the sub-sub-areas are shown in Table III.

Concentration of almost all size/age groups of the population in Rajahmundry provides the overall picture of the size structure in what may be considered as the central area of distribution of the stock. The rates of growth in terms of length and weight have been measured to a certain extent, though attempts at tracing seasonal growth rates or comparative growth rates from year to year remain to be completed. This aspect is therefore not discussed in detail. General assessment from field and laboratory studies shows that maximum growth in weight occurs in the 'large' prawns, of length 121 to 180 mm (carapace lengths 35 to 54 mm) and count 6 to 20 heads-on per lb (13 to 44 per kg). The average size in the commercial fishery in this sub-area is at lengths of 81 to 100 mm (carapace lengths 22 to 28 mm) and weight 30 to 60 per lb (66 to 132 per kg).

This concentration of all size groups at Rajahmundry and Dowlaishwaram is in the immediate vicinity of a recruitment area at Dowlaishwaram. The concentration diminishes towards Kovvur then increases slightly as one moves upstream to Polavaram. All the size-groups in the population are maturing by May and June. Almost 75 percent of males and 30 percent of females of medium and large sizes (100 to 170 mm) are mature.

5.1.1.2 Fishable biomass: Fig. 6 and Table V show the monthly biomass indices in each year. Each monthly index is a weighted mean (i.e., areal weightage) of the four sub-sub-areas, viz: Rajahmundry, Dowlaishwaram, Kovvur and Polavaram. The monthly index reaches a maximum in April, May or June each year and declines rapidly in July when jaruguvala operation ceases.

During 1964 the catch-effort indices in each month were generally high in each sub-sub-area (Table V). In this year, even by January the index of population biomass was high and continued to show improvement up to July. In 1965 on the other hand, the total biomass index was greatly reduced, particularly in the second half of the season. Slight recovery was indicated in 1966, especially in the months of April, May and June.

TABLE V

Monthly biomass indices (January - June) in sub-area I

Month	1963	1964	1965	1966
January	0.1947	0.1467	0.1419	0.1557
February	0.1950	0.2240	0.1893	0.1843
March	0.1636	0.2449	0.1311	0.1302
April	0.2017	0.5111	0.1322	0.1858
May	0.2047	0.3239	0.1728	0.2000
June	0.1587	0.4870	0.1948	0.2249
Mean index	0.1864	0.3229	0.1603	0.1801

5.1.2 Season II As stated, the catch of the six months of season (July to December) is mainly by castnet because of flood conditions in the river. In the post-flood period of November and December, only one unit of jaruguvala is fishing. The total landings of prawn averaged 8.7 percent of the annual catch. Total yield for this season was 8.8 tons in 1963, 2.7 tons in 1964, and increased to 5.0 tons in 1965, and 10.3 tons in 1966.

The biomass indices of jaruguvala and castnet are not comparable in this sub-area even though each gear relates to separate seasons. The castnet is not considered satisfactory gear for deriving total population figures, since it does not take all the size groups in the population. Any figures on fishable biomass are therefore not comparable with "fishable biomass" as defined earlier.

5.1.2.1 Population characteristics: In July, August and September, in all the sub-sub-areas, 75 percent of the catch consists of berried females or females which have already spawned and have developing ovaries. About 90 percent of all females

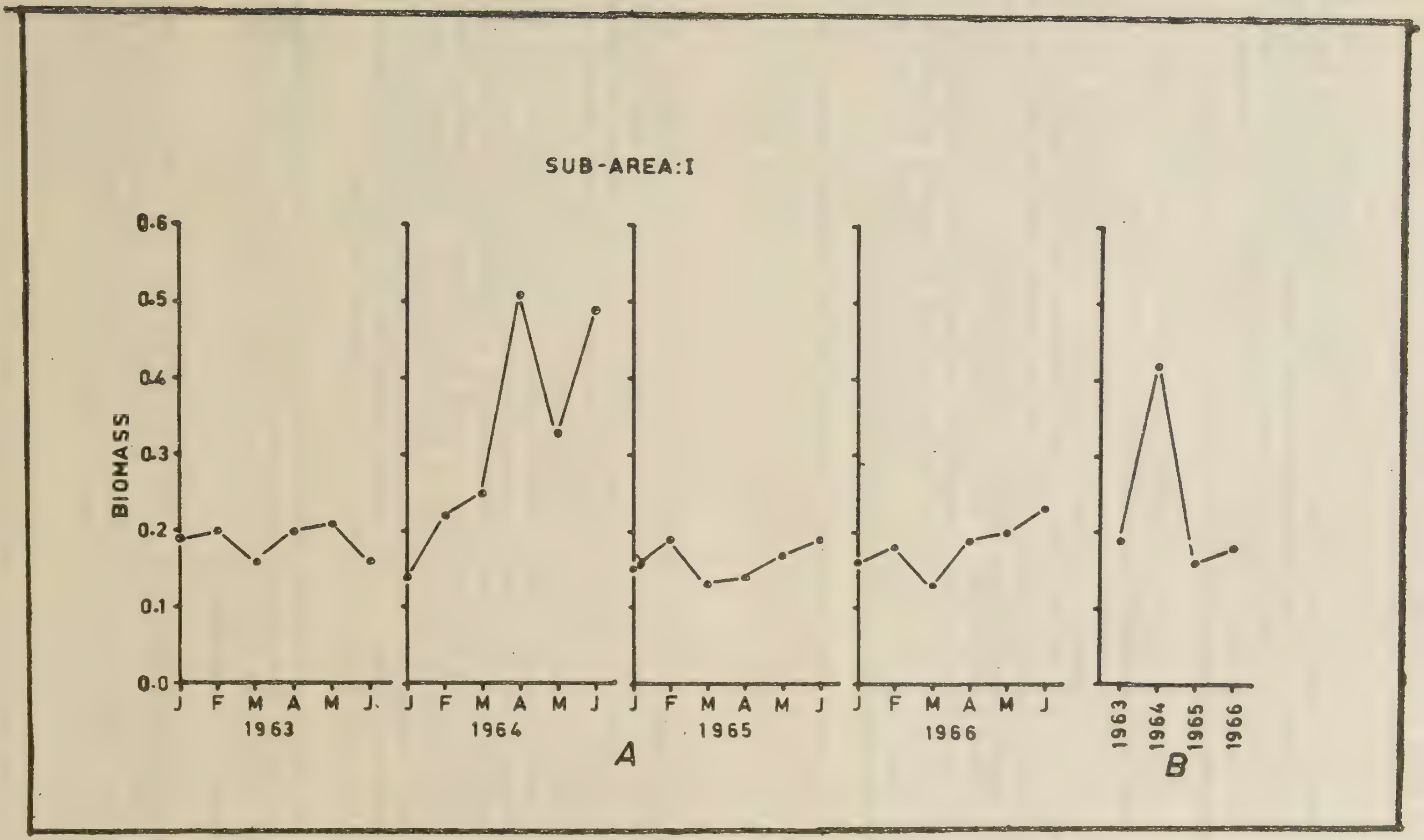


Fig. 6 (A) Fishable biomass indices of each month in the years 1963 to 1966 in the sub-area I, season I.

(B) Trend over the four years.

over 40 mm total length have external eggs or well developed ovaries. The spawning is protracted and lasts from July to October, with peaks in July and September. This spawning population is the remnant of the commercial fishery of season I.

Failure of the floods has a deleterious effect on survival of broods. If the contention that the larvae need to reach the estuary for further development and growth is correct (Ibrahim, 1962; Anon., 1965), then this is a further factor causing fluctuations in the commercial fishery. The delay in occurrence of floods in July or their early cessation in October would probably retain the early-spawned and late-spawned larvae in the stretch between the anicuts and would result in high mortality.

Delay in floods also allows jaruguvala fishing to continue up to the middle of July, thereby reducing the residual spawning population.

During season II there is intense recruitment of juveniles (10 to 20 mm) during October to January or February, at the anicuts in Dowlaishwaram sub-sub-area (Ibrahim, 1962). The juvenile mortality is quite appreciable before recruitment to the commercial fishery because of harvesting of this size group for marketing. Waves of juveniles move up the anicut during these four months. The intensity of occurrence varies with flow of water over the anicut, which is only one of the several reasons for this variation. Observations show that very low night temperatures also adversely affect it. There are about 5,000 of these juveniles per kg. About 40 kg are caught in four hours of collection each night in the peak period (Rajyalakshmi, 1968).

How far these factors affect the commercial population and whether these activities should be controlled is yet to be assessed. However, this intense harvesting prior to recruitment might be partly responsible for the high fluctuations in the yields.

5.2 Sub-area II

5.2.1 Fishable biomass

Prawn fishing in sub-area II is by castnet, the total catch representing 8.4 percent of the yield of the total river stretch. Annual yields for 1963 to 1966 are shown in Table I. During 1965 the prawn season extended from January to August, while in all the other years the season was from January to June or to the middle of July. Commercial concentrations in this sub-area are in Dummagudem and in its adjacent sub-sub-area, Bhadrachalam. From Bhadrachalam to the next sub-sub-area, Kondamodalu, it is almost a non-productive zone as far as prawn yield is concerned. Landings are composed predominantly of medium and larger sized prawns. Medium sizes are 20 to 60 heads-on per lb (44 to 132 per kg), total length 81 to 120 mm, carapace lengths 22 to 34 mm; large prawns are 6 to 20 heads-on per lb (13 to 44 per kg), total length 121 to 180 mm, carapace lengths 35 to 54 mm. The landings are therefore representative of the larger sizes and do not give a figure of fishable biomass comparable with that obtained from jaruguvala landings.

In this sub-area, the highest biomass indices fall during the months of maximum yield, March to June each year. The yearly maxima were 0.1750 in April 1963, 0.2564 in March 1964, 0.1584 in April 1965 and 0.1037 in April 1966. This seasonal predominance corresponds to season I of sub-area I.

5.2.2 Population characteristics

The information on this aspect is rather incomplete, due to the selectivity of the gear. Large prawns predominate in the catches at all times. The breeding period, with two periods of heightened spawning activity, corresponds to that of sub-area I. The effects on survival of larvae by the delayed floods would also be similar.

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SOME OBSERVATIONS ON THE BIOLOGY OF THE FRESHWATER PRAWN *Macrobrachium lanceifrons* (DANA), WITH NOTES ON THE FISHERY

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Abstract

The paper reports some observations on the development of *Macrobrachium lanceifrons* (Dana), spawned in aquaria. Rearing techniques developed for this species should also be applicable to larger species of freshwater prawn.

Notes on the shrimp fishery in Laguna de Bay are also presented.

OBSERVATIONS SUR LA BIOLOGIE DE LA CREVETTE D'EAU DOUCE *Macrobrachium lanceifrons* (DANA), ET NOTES SUR LA PECHERIE DE CETTE ESPECE

Résumé

Les auteurs rendent compte d'observations faites sur le developpement de *Macrobrachium lanceifrons* (Dana) nés en aquarium. Les techniques d'élevage mises au point pour cette espèce devraient pouvoir s'appliquer également à d'autres crevettes d'eau douce de plus grande taille.

La communication renferme aussi des notes sur la pêcherie de crevettes de Laguna de Bay.

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OBSERVACIONES SOBRE LA BIOLOGIA DEL LANGOSTINO DE AGUA DULCE *Macrobrachium lanceifrons* (DANA), Y NOTAS SOBRE LA PESQUERIA

Extracto

En este trabajo se presentan algunas observaciones sobre el desarrollo de *Macrobrachium lanceifrons* (Dana), cultivado en acuarios. Las técnicas de cría empleadas para esta especie pueden aplicarse también a otras especies mayores de langostinos de agua dulce.

Se dan igualmente notas sobre la pesca del camarón en la Laguna de Bay.

1 INTRODUCTION

The freshwater prawn Macrobrachium lanceifrons (Dana), locally called "hipon-tagunton", is one of the important aquatic resources of Laguna de Bay, Philippines. Large specimens are especially esteemed as food by the people in the area, and it is a welcome substitute when fish becomes scarce in the market. Not only does it serve as human food but it is also an important duck food, supplementing the snails which are the major food of the ducks. This prawn is rather small compared with commercial marine species and with Macrobrachium rosenbergii (de Man), the giant freshwater prawn.

In Laguna de Bay, three families of prawns occur, namely, the Palaemonidae, represented by M. lanceifrons, the Atyidae, represented by Caridina gracilirostris (de Man), and the Penaeidae, represented by Metapenaeus affinis (H. Milne Edwards).

Of these species, M. lanceifrons is the most common, C. gracilirostris is also common but, due to their very small size, these prawns are only collected when they occur in swarms at certain periods of the year. M. affinis is rare in the lake.

Considering the importance of M. lanceifrons in the economy of the Laguna de Bay area, it is worthwhile to know something about its biology and its contribution to the economic welfare of the lakeshore communities. Information obtained on the biology of the species will provide data for management purposes.

The experimental rearing of this species was also a trial run of the techniques of rearing freshwater prawns in tanks or aquaria, with the hope of applying the same to bigger species of Macrobrachium found in freshwater areas in the country.

2 METHODS AND PROCEDURES

Specimens for identification were collected in Laguna de Bay. The work of Cowles (1914), Henderson and Matthai (1910), and Holthuis (1950), were used as reference in the identification of the species.

Live specimens of mature male and female M. lanceifrons, were placed in aquaria for biological observations. Spawning, hatching and development of the larvae were observed in the laboratory.

Production estimates were based on prawn catch data collected from motorized push nets, manual push nets and prawn brush shelters in Laguna de Bay. The number of these gears that operate around the lake was taken from the census report of the evaluation team of the Limnology Project. Weight and sex ratio were determined from the samples collected. Species composition of the prawn catches sampled were also determined.

3 DESCRIPTION OF ADULT

The taxonomy of Macrobrachium lanceifrons (Dana) was studied by Cowles (1914), who, like the majority of earlier workers, used the name Palaemon for this genus. The help of Mr. Agustin Umali, Ichthyologist, of the National Museum, was sought in the identification of the species.

The rostrum is laterally flattened, divided into an upper (wider) and lower (narrower) region by a ridge. It bears 10 to 13 dorsal teeth, covering the entire length, and 3 to 5 ventral teeth. The tip of the rostrum is slightly curved upwards in full grown individuals but straight in the young. Antennal spines are present on the carapace, which is always smooth and shiny. Each antennule bears two flagella (upper and lower); the upper consists of two rami fused in the basal part; the lower pair is single. The first and second pairs of legs are chelate; the second is usually much longer and more robust than the first. The carpus of the first pair of legs extends beyond the antennal scale, with stiff hairs sparsely distributed. The second pair of walking legs or chelipeds are equal in length in young specimens but unequal in fully grown ones; a velvety coat of hairs is present in fully grown males on the mobile finger, except on its tip. The third, fourth and fifth pairs of walking legs are provided with stiff hairs in rows.

The second abdominal somite overlaps the first and third somites. The telson has four apical spines, of which the outer pair are shorter than the inner. Four setae are present on the mid-apical margin, between the inner pair of spines. Two pairs of spines are situated on the dorsal margin of the telson.

Fully grown males can best be distinguished from fully grown females by the length and shape of the second leg or cheliped. In the male, this is longer and is provided with felted hairs on the mobile finger, (Fig. 1).

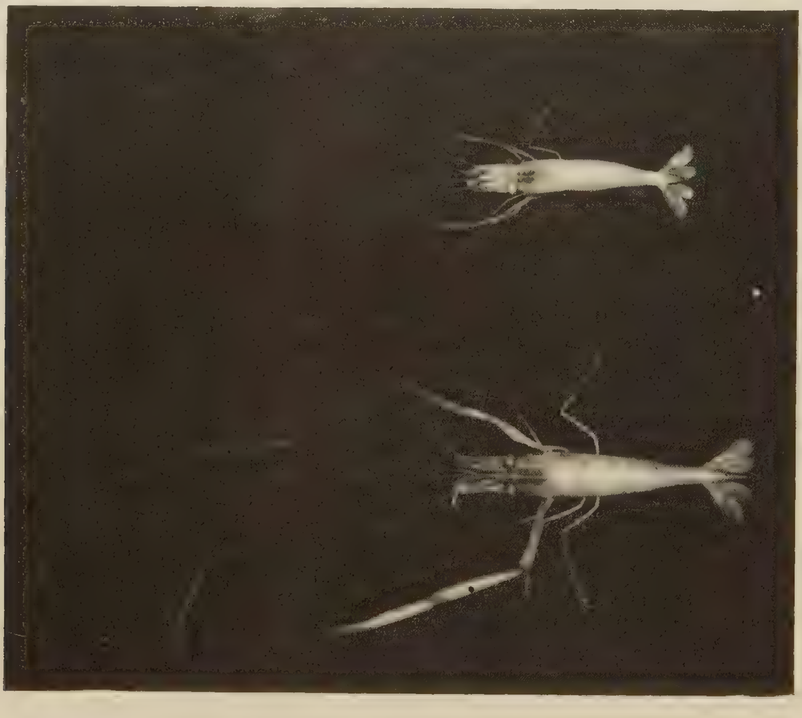


Fig. 1 Adult Macrobrachium lanceifrons (Dana); (Female shown on top and the male below).

Adults caught in Laguna de Bay range in length from 26 to 61 mm (from tip of rostrum to tip of telson). The average length is 43.0 mm and the average weight 0.45 g. There are more females than males in all length-groups below 50 mm but all the largest specimens are males. Details of the length-frequency distribution and of variations in the sex-ratio with respect to length are given in Table I.

TABLE I

Length-frequency distribution for sexes combined and separately (with percentages of total sample) and sex-ratio of M. lanceifrons from Laguna de Bay

Total length (mm)	Males and Females	Males : % of total	Females : % of total	Ratio F/100 M
26 - 27	82	36 : 2.6	46 : 3.3	127
28 - 29	136	41 : 2.9	95 : 6.7	231
30 - 31	298	59 : 4.2	239 : 17.0	405
32 - 33	131	47 : 3.3	84 : 6.0	178
34 - 35	179	37 : 2.6	142 : 10.1	383
36 - 37	161	20 : 1.4	141 : 10.0	705
38 - 39	73	21 : 1.5	52 : 3.7	249
40 - 41	52	4 : 0.3	48 : 3.4	1200
42 - 43	109	24 : 1.7	85 : 6.0	354
44 - 45	66	10 : 0.7	56 : 4.0	560
46 - 47	58	14 : 1.0	44 : 3.1	314
48 - 49	7	2 : 0.1	5 : 0.4	250
50 - 51	24	16 : 1.1	8 : 0.6	50
52 - 53	18	12 : 0.8	6 : 0.4	50
54 - 55	5	5 : 0.3	- : -	0
56 - 57	4	4 : 0.3	- : -	0
58 - 59	3	3 : 0.2	- : -	0
60 - 61	1	1 : 0.1	- : -	0

4 FECUNDITY

Females of M. lanceifrons start to produce eggs when about 30 mm in length. The eggs are oval in shape and average 0.66 by 0.54 mm. The specimens examined with eggs ranged from 30 to 55 mm. The average number of eggs per small female is about 179 while the number of eggs produced by large females is 781 (Table II).

TABLE II

Fecundity of Macrobrachium lanceifrons found in Laguna de Bay

Total length (mm)	Average number of eggs	Ovigerous females
30 - 31	179	3
32 - 33	194	13
34 - 35	210	25
36 - 37	242	25
38 - 39	264	3
40 - 41	321	13
42 - 43	437	15
44 - 45	450	11
46 - 47	528	16
48 - 49	551	10
50 - 51	605	6
52 - 53	654	8
54 - 55	781	5

Table II shows that females with eggs occur frequently in the 34 to 37 mm size group, but as they increase in size, the number of females with eggs decreases. Additional data are being collected to confirm this observation.

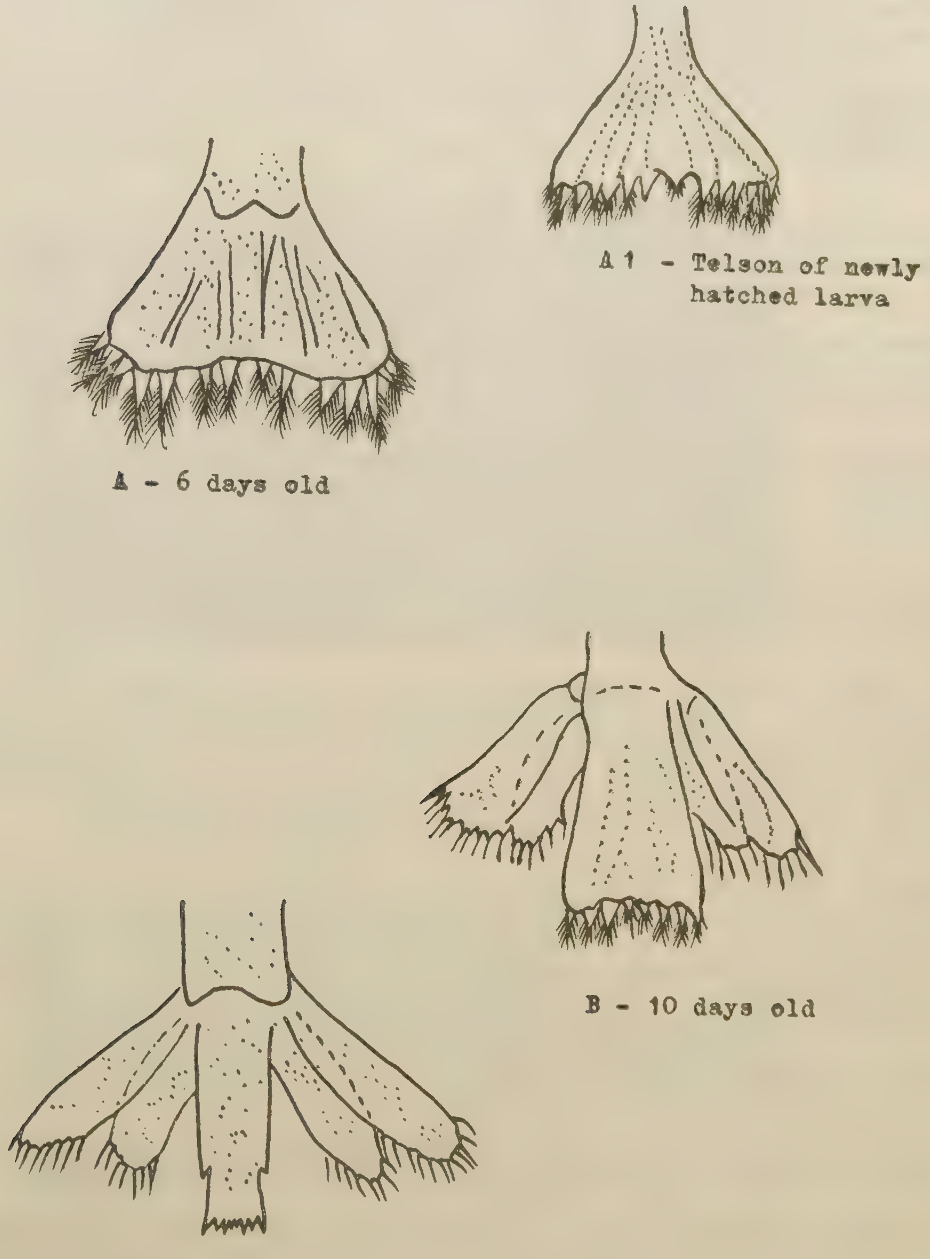
The data obtained indicated that females of M. lanceifrons become sexually mature at a length of 30 mm, although an unpublished report by Villamater mentions mature prawns of 20 to 35 mm. In the present paper, only females with eggs on their pleopods were considered mature.

5 LARVAL DEVELOPMENT

Adult prawns were successfully kept in aquaria for a long period without aeration. Specimens collected from the lake were sexually ripe females, some with eggs already deposited on their pleopods.

Spawning was satisfactorily achieved by selecting ripe females and pairing them with males at the ratio 1:1. A sexually ripe female can easily be determined by the presence of a green coloured mass that could be seen through the dorsal portion of the carapace, and brown-red chromatophores on the external wall of the ovary. It was found that prior to deposition of eggs on the pleopods, molting took place. After six days, eggs were already attached to the pleopods. Mating was, however, not closely observed. The eggs were hatched after 22 days of incubation at room temperature of 25° to 28°C. Ling and Merican (1961) observed that in the case of M. rosenbergii eggs hatched after about 19 days of incubation. The eggs were green in colour at the early stage of development, becoming orange when about to hatch.

Newly hatched larvae possess the following characteristics; antennal scale with 4 distinct segments at tip and with setae on anterior edge; rostrum very small and slender, curved downwards; eyes held close to head; three pairs of maxillipeds with exopods bearing four setae each; telson broad and triangular bearing 14 plumose spines; the innermost pair of spines is very small (Fig. 2).



A 1 - Telson of newly hatched larva

A - 6 days old

B - 10 days old

C - 15 days old

Fig. 2 Development of the larval telson of M. lanceifrons.

The triangular form of the telson remained unchanged up to the 6th day (Fig. 2A). By the 10th day development of the uropods was completed and the telson was distinctly articulared with the last abdominal somite; it was rather narrower than previously and bore 8 pairs of spines, the innermost pair being very small (Fig. 2B). All five pairs of walking legs were well developed at this period. Larvae from the 11th to the 15th day after hatching showed little change. The uropods became larger and the telson narrowed; the terminal spines changed in size but not in number and a pair of lateral spines appeared (Fig. 2C).

Most of the young prawns that had successfully hatched died after 15 days. The cause of such mortality was not known. However, it might have been due to lack of food or to the chemical composition of the water. Both are vital in the development of the larvae. Larvae reared in lake water survived for a longer period. According to Ling and Merican (1961), young prawns of this kind need saline water at a certain stage of development.

Larvae when 27 days old had rudimentary pleopods. By the 31st day the fifth pair of walking legs was longer than the first four and the inner lateral portion of the dactyl was armed with 14 long straight spines. Legs 1 to 4 each bore 8 long terminal spines.

At the age of 45 days, 5 pairs of walking legs and pleopods were completely developed. Young prawns at 58 days had 8 dorsal and 3 ventral rostral teeth. Body length was 11 mm. At this stage development of the larvae was complete.

The young prawns are predominantly plankton consumers. They start to feed on fish flesh and vegetable matter at the age of 70 days. Prior to this period the young did not feed on such kinds of food.

Young prawns that survived were kept in the laboratory up to about 3 months. They then measured 16.2 mm long. From 87 days, molting was observed to be regular, with an interval of 10 to 11 days. At this stage they remained mostly at the bottom.

The rate of growth was observed to be rather rapid. This observation, however, needs further investigation. The fast rate of growth here may be due to sparse population in the aquaria, and inadequate samples collected.

It is possible that M. lanceifrons spawn all the year round, depending upon the availability of food. This is deduced from the fact that after about one month from spawning the same female deposited another batch of eggs on its pleopods. This female was intensively fed with chopped fish while the prawns in the other aquaria which did not spawn were fed irregularly. Prawns collected from the lake carried eggs most of the year. It is possible that they have peak periods of spawning.

The aquaria where the larvae were hatched were enclosed with lawanit boards with black paint to eliminate bright light and the distrubances created in the laboratory. The larvae were observed to be disturbed by mechanical movements. All newly hatched larvae were observed to be easily attracted to light and actively swam in groups near the walls of the aquarium. Their manner of locomotion is vertical with the head pointing downward. This movement gradually changed as they grew older.

6 THE PRAWN FISHERY

There are three major gears used in harvesting prawns in Laguna de Bay, namely, the motorized push net, the manual push net and the prawn brush shelter.

The motorized push net (Fig. 3) produces the bulk of the prawn catches in the lake. Sub-samples from catches consisted of 91.8 percent prawns, 2.5 percent fish and 5.6 percent snails by number; the corresponding weights are indicated in Table III.

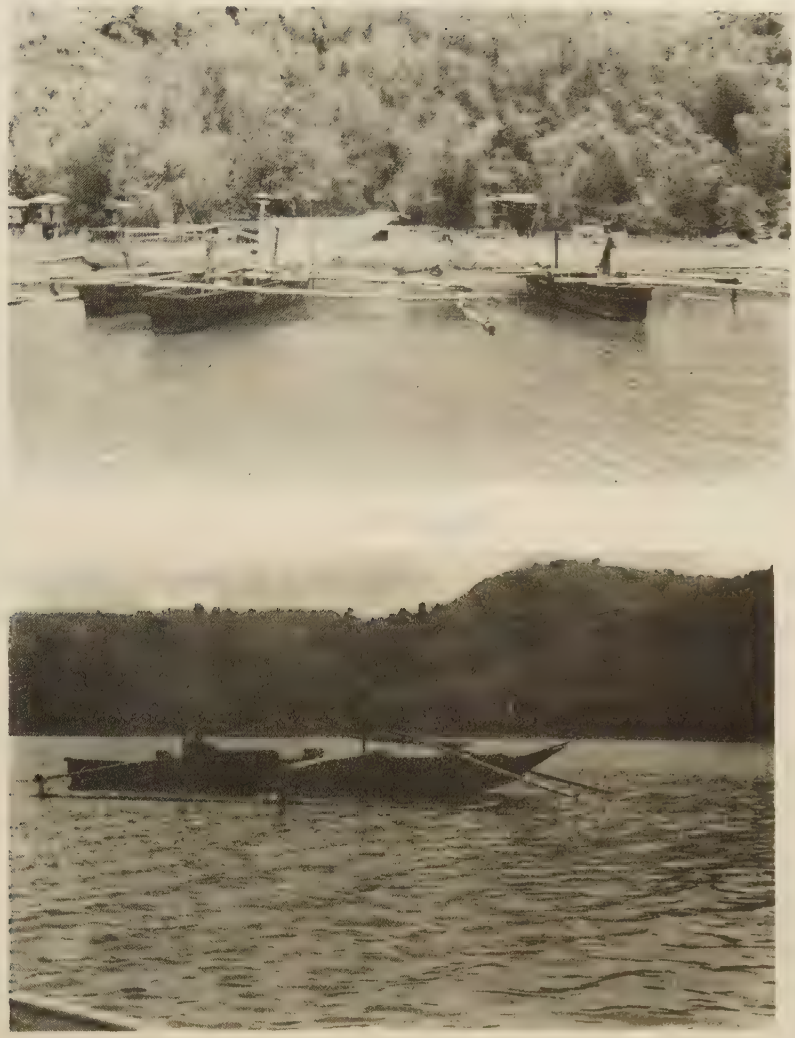


Fig. 3 Motorized push net outfit.

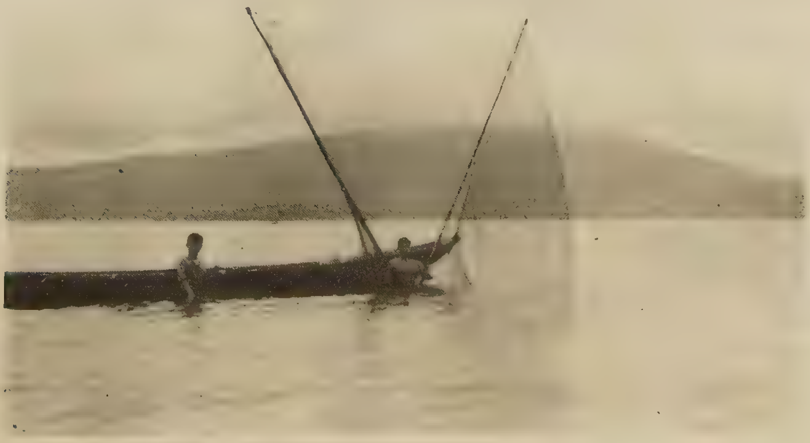


Fig. 4 Manual push net.

TABLE III

Composition of sub-sample of catch taken by motorized push net

	Number	Weight (g)	Number (%)	Weight (%)
Prawns	583	384.7	91.8	90.1
Fish (Gobies)	16	11.2	2.5	2.6
Snails	36	22.5	5.6	5.3
Vegetable Materials	-	8.0	-	1.9
Total	635	426.4	99.9	99.9

TABLE IV

Composition of sub-sample of catch taken by manual push net

	Number	Weight (g)	Number (%)	Weight (%)
Prawns:				
M. lanceifrons	752	137.3	90.3	87.9
C. gracilirostris	38	2.8	4.6	1.8
Fish:				
Therapon plumbeus	26	3.7	3.1	2.4
Mirogobius lacustris	15	2.6	1.8	1.7
Trichogaster pectoralis	1	9.5	0.1	6.1
Total	832	155.9	99.9	99.9

TABLE V

Composition of sub-sample of catch taken by brush shelter

	Number	Weight (g)	Number (%)	Weight (%)
Prawns:				
M. lanceifrons	434	273.2	85.4	84.5
C. gracilirostris	63	6.0	12.4	1.8
Fish:				
Glossogobius giurus	4	17.5	0.8	5.4
Ophiocara aporos	3	8.5	0.6	2.6
T. plumbeus	4	2.2	0.8	0.7
Vegetable Materials	-	16.0	-	4.9
Total	508	323.4	100.0	99.9

The manual push nets (Fig. 4) are operated in shallow areas of the lake, mostly near the shore. This gear catches 90% prawns by number or 87.9% by weight (Table IV).

On the other hand, the brush shelter catches 85.4% prawns by number or 84.5% by weight (Table V). Caridinia gracilirostris is caught in small quantities by all three methods.

The figures presented on catch composition merely indicate selectivity of gear in favour of the prawns. There is no difference in size composition of the prawns caught.

The prawn fishery of Laguna de Bay contributes considerably to the duck farming industry which is a flourishing endeavour around the lake. If not fed to the ducks the prawns are dried and transported to other markets in the provinces.

It has been reported earlier (Rabanal, Acosta and Delmendo, 1964) that the withdrawal of prawns from the lake is about 1 ton per hectare per year. Recent observations reveal that this quantity is decreasing from year to year. An ad hoc survey made in 1968 indicated a reduction in shrimp production. A full report on this survey is being prepared.

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ABBREVIATED LARVAL DEVELOPMENT IN CARIDEAN SHRIMPS AND ITS SIGNIFICANCE IN THE ARTIFICIAL CULTURE OF THESE ANIMALS

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Abstract

The author's studies on the larval development of one penaeid and more than 40 caridean shrimps have produced information applicable to the development of successful culture techniques. Among these species, Palaemonetes paludosus, Synalpheus brooksi, Glyphocrangon spinicauda, Glyphocrangon sp., Systellaspis debilis, and Thor sp. had abbreviated or direct development. Comparison of survival to metamorphosis in the laboratory between Thor floridanus, with a typical long pelagic larval life, and Thor sp., with abbreviated development, shows that many more of the latter attain the post-larval stage despite the greater fecundity of the former. These data indicate that the artificial culture of animals with abbreviated or direct development will achieve the best results. Among the shrimps thus far studied, the large fresh and brackish water shrimp of the genera Macrobrachium and Cryphiops appear best suited to culture from a commercial standpoint. Experiments on the culture of M. carcinus, M. rosenbergii, M. acanthurus, M. ohione, and others have been inconclusive. It is significant that these species all have a long larval life. Pond-culture experiments on forms with abbreviated development such as M. jelskii, M. quelchi, M. borellii, M. potiuna, M. brasiliense, and M. iheringi, all of which are found in Central and South America, are recommended. Forms with similar developmental patterns can be found in other parts of the world.

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LE DEVELOPPEMENT LARVAIRE COURT DES *Caridea* ET SON IMPORTANCE DANS l'ELEVAGE DE CES ANIMAUX

Résumé

Les études de l'auteur sur le développement larvaire d'une espèce de *Penaeidea* et de plus de quarante appartenant aux *Caridea* ont fourni des informations applicables à la mise au point de techniques efficaces d'élevage. Parmi les espèces examinées, *Palaemonetes paludosus*, *Synalpheus brooksi*, *Glyphocrangon spinicauda*, *Glyphocrangon* sp., *Systellaspis debilis* et *Thor* sp. connaissent un développement court ou direct. La comparaison *in vitro* du taux de survie jusqu'à la métamorphose entre *Thor floridanus*, dont la larve a une vie pélagique particulièrement longue, et *Thor* sp., à développement direct, révèle qu'un beaucoup plus grand nombre de cette dernière espèce parviennent au stade postlarvaire, bien que la première soit plus féconde. Ces données indiquent que c'est avec l'élevage des animaux à développement court ou direct que l'on obtiendra les meilleurs résultats. Parmi les crevettes étudiées jusqu'ici, les grands animaux d'eau douce ou d'eau saumâtre des genres *Macrobrachium* et *Cryphiops* paraissent être ceux qui se prêtent le mieux à l'élevage commercial. Les expériences conduites en matière de culture de *M. carcinus*, *M. rosenbergii*, *M. acanthurus*, *M. ohione*, etc., n'ont pas été concluantes. Il est significatif que toutes ces espèces ont une longue vie larvaire. Il est recommandé de procéder à des expériences d'élevage en étangs de formes à développement court telles que *M. jelskii*, *M. quelchi*, *M. borellii*, *M. potiuna*, *M. brasiliense* et *M. iheringi*, qui se trouvent toutes en Amérique centrale et en Amérique du Sud. Il existe dans d'autres parties du monde, des formes présentant des caractéristiques analogues du point de vue du développement larvaire.

DESARROLLO LARVAL ABREVIADO DE LOS CAMARONES CARIDIFORMES Y SU IMPORTANCIA EN EL CULTIVO ARTIFICIAL DE ESTOS ANIMALES

Extracto

Los estudios del autor sobre el desarrollo larval de un peneido y de más de 40 camarones caridiformes han proporcionado información aplicable al desarrollo de técnicas de cultivo favorables. Entre estas especies, *Palaemonetes paludosus*, *Synalpheus brooksi*, *Glyphocrangon spinicauda*, *Glyphocrangon* sp., *Systellaspis debilis* y *Thor* sp. tenían un desarrollo reducido o directo. La comparación en el laboratorio de la supervivencia a la metaformosis entre *Thor floridanus*, con una típica y larga vida pelágica larval, y *Thor* sp. con desarrollo abreviado, indica que de estos últimos son muchos más los que llegan a la fase postlarval, a pesar de la mayor fecundidad de los primeros. Estos datos muestran que el cultivo artificial de animales con desarrollo abreviado o directo conseguirá los mejores resultados. Entre los camarones estudiados hasta ahora los que mejor se adaptan al cultivo, desde el punto de vista comercial, son los grandes camarones de aguas dulces y salobres de los géneros *Macrobrachium* y *Cryphiops*. No han sido concluyentes los experimentos sobre el cultivo de *M. carcinus*, *M. rosenbergii*, *M. acanthurus*, *M. ohione* y otros. Es interesnte observar que todas estas especies tienen una prolongada vida larval. Se recomiendan experimentos de cultivo en estanques con formas de desarrollo abreviado tales como *M. jelskii*, *M. quelchi*, *M. borellii*, *M. potiuna*, *M. brasiliense* y *M. iheringi*, todos los cuales se encuentran en América del Sur y Central. En otras partes del mundo se pueden encontrar formas con tipos de desarrollo similar.

1 INTRODUCTION

In the course of nine years of study concerning the larval development of penaeidean, caridean, and stenopodidean shrimps of South Florida, some 40-odd species, the great majority belonging to the Caridea, have been investigated. Larval development within the Suborder Natantia is quite varied. At one end of the spectrum are the Penaeidea, in which the primitive developmental sequence begins with a series of free-swimming naupliar stages and includes up to twenty planktonic stages (Heldt, 1938). At the opposite end are certain species of the Caridea and Stenopodidea in which direct development occurs, i.e. the newly-hatched individual is similar to the adult in form and therefore undergoes no metamorphosis.

The vast majority of the Natantia have developmental patterns lying somewhere between these extremes. The development of all of the Caridea and Stenopodidea thus far investigated is abbreviated when compared with that of the Penaeidea in that none of these has been observed to have a free-swimming nauplius; none the less, development within these two groups is extremely variable.

In the Caridea, species of which occupied most of the author's attention, abbreviated and direct development occur largely in forms from cold water (both deep sea and high latitudes), fresh water, and those living inquilinistically. Of approximately 40 species of Caridea studied, six showed abbreviated or direct development: Palaemonetes paludosus, a common freshwater form in South Florida (Dobkin, 1963); Synalpheus brooksi, an inquiline of the loggerhead sponge (Dobkin, 1965 a); Glyphocrangon spinicauda, Glyphocrangon sp., and Systellaspis debilis, deep water forms from off the Florida Coast (Dobkin, 1965 b); and Thor sp., an inhabitant of turtle grass in shallow water marine areas (Dobkin, 1962 and 1968). Several others, however, appeared to be evolving toward abbreviated development, and a review of the literature on caridean development uncovered many more species characterized by a decreased number of planktonic larval stages (abbreviated development) or complete suppression of planktonic larvae (direct development).

While the studies were being pursued, the author became interested in the prospects for pond culture of shrimps and prawns. In particular, the fresh and brackish-water shrimps of the genera Macrobrachium and Cryphiops held great interest. It became obvious that as the early developmental stages of most organisms are the most sensitive to environmental stresses, and that as it is at this time in the life history of most organisms that the greatest mortality takes place, that shrimp undergoing abbreviated or direct development might be more successfully cultured than those with a longer developmental sequence. This then, in brief, is the thesis of this paper.

2 EXPERIMENTAL EVIDENCE

Evidence to support this thesis was obtained from laboratory rearing of larvae. The methods used are reported in detail in the literature cited above, but briefly, larvae were reared in plastic compartmented boxes, one larva per compartment, in 50 to 75 cc, of filtered water. The water was changed every day or every other day, at which time the larvae were fed the newly-hatched nauplii of the brine shrimp Artemia salina. In the species having abbreviated development, the larvae were generally not fed at all.

Although it was not possible to rear the larvae of any species of Cryphiops or Macrobrachium with abbreviated or direct development because of the absence of such forms in the area under study, it was possible to compare survival to metamorphosis in two species of Thor, two species of Palaemonetes, and two species of Synalpheus. In each of these genera a species having abbreviated or direct development as well as one having a longer developmental sequence were studied and compared.

The members of the genus Palaemonetes that were studied were P. intermedius, a brackish-water and marine form found in salinities of 6 to 38°/oo (Tabb and Manning, 1961), and P. paludosus, a fresh to brackish-water species living in 0 to 10°/oo (Tabb and Manning, ibid.). Of 25 specimens of P. intermedius reared, none attained the postlarval stage after six or seven instars. This cannot be considered a valid statistical sample, but additional data are provided by Broad (1957) who worked on P. vulgaris and P. pugio. Of 100 larvae of P. pugio fed Artemia nauplii, 65 reached the postlarva stage generally after seven instars, and of 390 P. vulgaris fed the same food, 131 became postlarvae after about the same number of larval stages. P. intermedius, P. pugio, and P. vulgaris appear to be evolving in the direction of abbreviated development, which is very common in fresh and brackish-water species of the family Palaemonidae. Palaemonetes paludosus has abbreviated development, passing through three larval stages before attaining the postlarva. Of 302 larvae reared, 200 reached the postlarva in five to ten days without being fed. Much less care was required to rear the larvae of P. paludosus than those of P. intermedius, and yet 66 percent of the larvae of the former successfully completed metamorphosis compared with 36 percent of the latter.

In the genus Synalpheus, S. apioceros and S. brooksi were the two species most carefully studied. Development is direct in S. brooksi and all specimens are postlarval on hatching. By contrast, of 72 specimens of S. apioceros reared, not a single one reached metamorphosis or even approached it. The most advanced specimens reached the fifth larval stage and it was estimated that they required several more molts before attaining the postlarva.

Studies were made on Thor floridanus and Thor sp., the former with a long pelagic life and the latter with abbreviated development. Specimens of Thor sp. generally attained the postlarval stage after 48 hours without being fed. Mortality of the larvae was extremely low, only 10 out of 356, or less than three percent, succumbing prior to metamorphosis. It was possible to rear four generations of this species during 1963 and 1964 in running sea water in small aquariums with very little care other than occasional feeding. Siblings bred freely within these tanks. Generation time during the summer was about two months. Of 161 specimens of Thor floridanus reared, 28 became postlarvae. These 28 were bred further and three generations of this species were achieved, but with significantly more effort, and with fewer adults resulting from these efforts.

Initial attempts to rear larvae of Cryphiops caementarius from Peruvian waters and Macrobrachium acanthurus from Florida have resulted in all specimens of both species succumbing prior to metamorphosis. Both of these forms have a long planktonic larval life, C. caementarius in fact having been reared through ten instars without attaining the postlarva.

3 CARIDEANS WITH ABBREVIATED OR DIRECT DEVELOPMENT

Tables I and II are the result of a fairly complete literature survey extending through the early part of 1964, and indicate carideans which have been reported to undergo abbreviated or direct development. The information on many of these species is admittedly very limited and may be based on as little evidence as a very large egg or a late embryo removed from the egg membranes and examined. Nevertheless, they will probably be of some value in regard to the problem under consideration.

To this list should be added Macrobrachium jelskii, M. quelchi, and M. brasiliense which have large eggs indicative of abbreviated development. All three are found in Latin America. Future investigations will undoubtedly add many more species to this list.

4 DISCUSSION AND RECOMMENDATIONS

The most successful experiments in the aquiculture of shrimps have been those of Fujinaga and his associates (personal communication) with Penaeus japonicus. This success has been accomplished in spite of the large number of larval stages in this

TABLE I

Members of the Subfamily Palaemoninae reported to undergo abbreviated development

Name in current usage	Name larvae described under	Paper dealing with development	Egg-size (mm) (along greater axis)	No. of larval stages	Habitat
Macrobrachium lamarrei (H.Milne Edwards)	Palaemon lamarrei (H.Milne Edwards)	Henderson and Matthai (1910) Rajyalakshmi (1961)	1.75	3	fresh and brackish waters
M. borellii (Nobili)	Palaemon borellii Nobili Macrobrachium borellii (Nobili)	Sollaud (1923) Boschi (1961)	2.0 1.6	?	fresh water " "
M. raridens (Hilgendorf)	Palaemon paucidens Hilgendorf	Sollaud (1923)	3.0 (early) 3.5 (late)	*	fresh water
M. sollaudii (De Man)	Palaemon sollaudi De Man	Sollaud (1923)	3.7 (late)	*	fresh water
M. dux (Lenz)	Palaemon dux Lenz Palaemon lenzi De Man	Sollaud (1923) " "	?	*	fresh water " "
M. potiuna (Fr. Müller)	Palaemon potiuna Fr. Müller	Sollaud (1923)	1.1 - 2.0	3	fresh water
M. iheringi (Ortmann)	Palaemon iheringi Ortmann	Sollaud (1923)	1.5 - 2.0	?	fresh water
M. pilimanus (De Man)	Palaemon pilimanus De Man	Sollaud (1923)	1.2 - 2.1	?	fresh water
Palaemon pandaliformis (Stimpson)	Palaemonetes cubensis Hay	Sollaud (1923)	1.6 - 1.7 (late)	*	fresh and brackish waters
P. mani (Sollaud)	Leander mani Sollaud	Sollaud (1914; 1923)	1.5 (late)	?	fresh water
P. modestus (Heller)	Palaemon nipponensis De Haan Leander modestus Heller	Shen (1939) Liu (1949)	?	2	fresh water " "
Palaemonetes sinensis (Sollaud)	Palaemonetes sinensis Sollaud	Sollaud (1923) Shen (1939)	1.3 - 1.4	2	fresh water " "
P. tonkinensis (Sollaud)	Coutierella tonkinensis Sollaud	Sollaud (1914; 1923)	1.2 - 1.6	*	fresh water
P. antennarius (H.Milne Edwards)	Palaemonetes varians (Leach) Palaemonetes varians lacustris Von Martens Palaemontes antennarius	Mayer (1881) Sollaud (1923) Sollaud (1930; 1932)	1.3 - 1.8 1.3 - 1.4	3	fresh water " "

* Indicates species for which only a late embryo was examined

TABLE I (continued)

Name in current usage	Name larvae described under	Paper dealing with development	Egg-size (mm) (along greater axis)	No. of larval stages	Habitat
P. mesopotamicus Pesta	Palaemonetes varians mesopotamicus Pesta	Sollaud (1923)	1.3 - 1.5	?	fresh water
	Palaemonetes mesopotamicus Pesta	Sollaud (1932)	1.3 - 1.4		" "
P. mesogenitor Sollaud	Palaemonetes punicus Sollaud	Sollaud (1923)	1.1 - 1.9	?	fresh water
	Palaemonetes mesogenitor Sollaud	Sollaud (1930; 1932)	" "		" "
P. paludosus (Gibbes)	P. paludosus (Gibbes)	Dobkin (1963)	1.1 - 1.8	3	fresh water
Pseudopalaemon bouvieri Sollaud	Pseudopalaemon bouvieri Sollaud	Sollaud (1923)	1.0 - 1.8	?	fresh water

TABLE II

Carideans (exclusive of Subfamily Palaemoninae) reported to undergo abbreviated development

Name in current usage	Name larvae described under	Author	Egg-size (mm)	No. of larval stages	Habitat
Systellapis debilis (A. Milne Edwards)	Acanthephyra debilis Systellaspis debilis	Kemp (1910) Gurney and Lebour (1941)	3.5 - 4.0	3 or 4	bathypelagic
Oplophorus spinosus (Brullé)	Oplophorus grimaldii	Gurney and Lebour (1941)	2.8 - 3.2	5	bathypelagic
Hymenodora glacialis (Buchholz)	Hymenodora glacialis	Stephensen (1935)	?	5	bathypelagic
Caridina denticulata (De Haan)	Caridina denticulata	Shen (1939)	0.73- 1.1	direct development	fresh water
Atya bisulcata (Randall)	Atya bisulcata	Edmondson (1929)	0.65	2 or 3?	fresh water
Troglocaris anophthalmus (Kollar)	Troglocaris schmidti	Matjasic (1958)	1.25	2 or 3	fresh water
Pasiphaea sivado (Risso)	Pasiphaea sivado	Williamson (1960)	1.0 - 2.0	4	upper sublittoral-bathyalbenthic

TABLE II (continued)

Name in current usage	Name larvae described under	Author	Egg-size (mm)	No. of larval stages	Habitat
P. tarda Kröyer	*P. tarda*	Williamson (1960), Elofsson (1961)	3.0	4?	bathyalbenthic
P. multidentata Esmark	*P. principalis* *P. multidentata*	Williamson (1960) Elofsson (1961)	2.0 - 2.4	4	bathyalbenthic
Parapasiphae sulcatifrons S.I. Smith	*Parapasiphae sulcatifrons*	Williamson (1960) (reviewed Kemp, 1910 and Stephensen, 1935)	3.7 - 5.0	4	bathyalbenthic
Conchodytes tridacnae Peters	*Conchodytes biunguiculatus*	Boone (1935)	?	direct development	inquiline
Alpheus heterochaelis Say	*Alpheus heterochaelis*	Brooks and Herrick (1892), Knowlton (personal communication)	ca. 0.4 - 1.0	1 to many 3	upper sublittoral
Synalpheus minus (Say)	*Alpheus minor* *Synalpheus minor*	Brooks and Herrick Coutière (1899)	ca. 0.5 ?	many *	inquiline "
Synalpheus neptunus (Dana)	*Synalpheus neptunus*	Coutière (1899)	1.25 - 2.5	*	inquiline
S. brevicarpus (Herrick)	*Alpheus saulcyi* var. *brevicarpus*	Brooks and Herrick (1892)	ca. 0.9	2	inquiline
S. longicarpus (Herrick)	*Alpheus saulcyi* var. *longicarpus*	Brooks and Herrick (1892)	ca. 1.0 - 1.1	direct development	inquiline
S. gambarelloides (Nardo)	*Synalpheus laevimanus*	Coutière (1898; 1899) Bourdillon-Casanova (1960)	0.75 ?	? 4	inquiline "
S. goodei Coutière	*S. goodei*	Gurney (1949)	?	3	inquiline
S. brooksi Coutière	*S. brooksi*	Dobkin (1965a)	0.94-1.58	direct development	inquiline
Bythocaris payeri (Heller)	*Bythocaris payeri*	Sars (1885)	?	direct development	bathyalbenthic
B. leucopis G.O. Sars	*B. leucopis*	Sars (1885)	?	direct development	bathyalbenthic
B. simplicirostris G.O. Sars	*B. simplicirostris*	Sars (1912)	?	direct development	bathyalbenthic

TABLE II (continued)

Name in current usage	Name larvae described under	Author	Egg-size (mm)	No. of larval stages	Habitat
Cryptocheles pygmaea G.O. Sars	*Cryptocheles pygmaea*	Sars (1912)	1.15	direct development	bathyalbenthic
Lebbeus polaris (Sabine)	*Spirontocaris polaris*	Stephensen (1916)	2.1	2 or 3	upper sublittoral-bathyalbenthic
L. groenlandicus (Fabr.)	*Spirontocaris* sp.	Stephensen (1935)	2.1	2 or 3?	upper sublittoral-bathyalbenthic
Chorismus antarcticus (Pfeffer)	*Chorismus antarticus*	Gurney (1937)	1.7	3	upper sublittoral-bathyalbenthic
Thor sp.	*Thor* sp.	Dobkin (1968)	0.84 - 1.4	2	upper sublittoral
Pandalus kessleri (Czerniavsky)	*Pandalus kessleri*	Kurata (1955)	?	1	upper sublittoral
Notocrangon antarcticus (Pfeffer)	*Crangon antarcticus*	Calman (1907)	1.4	3	?
Sclerocrangon ferox (G.O. Sars)	*Sclerocrangon salebrosus* *S. ferox*	Koelbel (1886) Wolleback (1906; 1908)	3.5 - 5.0	direct development	Lower sublittoral-bathyalbenthic
S. boreas (Phipps)	*S. boreas*	Sars (1890)	2.0 - 2.8	direct development	upper sublittoral-bathyalbenthic
Sabinea septemcarinata (Sabine)	*Sabinea septemcarinata*	Sars (1890)	3.0	3	upper sublittoral-bathyalbenthic
Glyphocrangon spinicauda A.Milne Edwards	*Glyphocrangon spinicauda*	Burkenroad (1942) Dobkin (1965b)	2.25 - 3.05	* ?	bathyalbenthic
G. granulosis Bate	*G. granulosis*	Bate (1888)	4.0	*	bathyalbenthic

* Only late embryos examined

species, and is the result of great technological skill employed by these workers. It is obvious, however, that this venture would not have been a commercial success if it were not for the fact that Fujinaga could sell his shrimp at an extremely high price while keeping his rearing costs relatively low. This favorable price/cost ratio does not exist in most areas.

Attempts at the aquiculture of species of Macrobrachium and Cryphiops have for the most part been inconclusive. Among the species studied have been Macrobrachium carcinus (Lewis, 1961), M. acanthurus and M. ohione (Schmittou, personal communication), M. rosenbergii (Ling, 1962; Ling and Merican, 1961), and Cryphiops caementarius (Boza, personal communication). The work on M. rosenbergii in Malaysia has been the most promising.

It is significant that all of these species have a relatively long planktonic life. To the author's knowledge, no species of Macrobrachium or Cryphiops exhibiting abbreviated or direct development has been the subject of pond culture experiments. It is the author's recommendation that these species be used in such experiments and his belief that the results will be well worth the effort. Based on the experimental evidence described above, forms with abbreviated or direct development attain the postlarval stage in greater numbers than those with a longer larval life, despite a lower fecundity. Elimination of the necessity for feeding and caring for large numbers of planktonic larvae would be a significant factor in lowering the costs of culture operations. The cost of providing large numbers of Artemia nauplii to the young stages of Penaeus japonicus in large measure prevented an earlier financial success of shrimp farming operations in Japan.

In many parts of the world the large fresh and brackish-water species of the genera Macrobrachium and Cryphiops are untapped fishery resources. In this day of expanding world population we cannot afford to allow such resources to remain unexploited. Building on the technological advances that have already been achieved we must accelerate our efforts in the field of aquiculture of commercially important species not only of shrimp, but of other fish and shellfish so as to help meet the nutritional requirements of future generations.

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ADDENDUM

Since the preparation of this paper in April, 1967, there have been significant advances in the culture of *Macrobrachium*. Ling's papers included in these Proceedings (Volume 3) showed the feasibility of the commercial rearing of *M. rosenbergii*, and Fujimura (unpublished data) has established a pilot plant for the production of the same species in Hawaii. *M. rosenbergii* raised in the latter experiments are being sold in Hawaii at prices advantageous to the shrimp farmer.

In the United States, experiments are underway on the rearing of *M. carcinus* and *M. acanthurus* (Dobkin, unpublished; Provenzano, unpublished). The author has reared *M. acanthurus* to metamorphosis in 43 days at 30°C. Although less success has been achieved in rearing the larval stages of *M. carcinus*, this animal will probably prove to be the better of the two for culture, because of its larger size and presumed faster growing rate. In Mexico, similar work is being done on *M. americanum*.

DETAILED SHRIMP STATISTICAL PROGRAM IN THE GULF STATES

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Abstract

The domestic shrimp fishery, centered in the Gulf States, has expanded rapidly during the past 20 years and is now the most valuable fishery in the United States. Despite the rapid rise in importance of this fishery, detailed statistical information was not available prior to 1955 to meet the needs of government and industry.

This paper describes the methods and procedures used in the collection and publication of detailed statistics in a program developed for the shrimp fishery of the Gulf of Mexico. Statistical data provided by this program are vital to the expanding economic and biological research programs of State and Federal agencies. In addition, industry is supplied with current and accurate information on shrimp supplies, prices, and market conditions, in order to plan their operations.

Development of this program was aided immeasurably by experience gained in a similar program for the North Atlantic fisheries which has been in operation at New England ports for many years.

E/54

PROGRAMME DE STATISTIQUES DETAILLEES SUR LES CREVETTES, ETATS DU GOLFE DU MEXIQUE

Résumé

Les pêches nationales de crevettes, concentrées dans les Etats du golfe du Mexique, se sont développées rapidement au cours des vingt dernières années et représentent actuellement, par leur valeur, la principale activité de pêche des Etats-Unis d'Amérique. Malgré l'accroissement rapide de l'importance de ces pêches, on ne dispose pas, pour la période antérieure à 1955, des renseignements statistiques détaillés dont auraient besoin le gouvernement et l'industrie.

L'auteur décrit les méthodes et les procédés utilisés pour recueillir et publier des statistiques détaillées dans le cadre d'un programme intéressant les pêcheries de crevettes du golfe du Mexique. Les données statistiques fournies par ce programme présentent une importance capitale pour les programmes de recherche économique et biologique en voie d'expansion entrepris par des organismes relevant des Etats ou du gouvernement fédéral. En outre, l'industrie reçoit, en vue d'établir le plan des opérations, des renseignements exacts et à jour touchant les disponibilités de crevettes, les prix et la situation du marché.

L'expérience acquise à l'occasion d'un programme analogue pour les pêches de l'Atlantique Nord, qui fonctionne dans les ports de Nouvelle-Angleterre depuis de nombreuses années, a représenté pour l'élaboration de ce programme une aide inestimable.

PROGRAMA ESTADISTICO DETALLADO SOBRE CAMARONES EN LOS ESTADOS DEL GOLFO DE MEXICO

Extracto

La pesquería nacional de camarones, cuyo centro se halla en los Estados del Golfo de México, se ha ampliado rápidamente durante los últimos 20 años y en la actualidad es la pesquería más valiosa de los Estados Unidos de América. No obstante el rápido incremento de esta pesquería, no existía información estadística detallada anterior a 1955 que respondiera a las necesidades del gobierno y de la industria.

En este trabajo se describen los métodos y procedimientos empleados en la recogida y publicación de estadísticas detalladas en un programa desarrollado para la pesquería camaronera del Golfo de México. Los datos estadísticos proporcionados por este programa son vitales para los crecientes programas de investigación económicos y biológicos de los organismos estatales y federales. Además, la industria dispone de información actual y exacta sobre los suministros de camarones, precios y condiciones del mercado para planificar sus operaciones.

Ha ayudado inmensamente al desarrollo de este programa la experiencia obtenida en un programa similar para las pesquerías del Atlántico Norte que se realizó durante muchos años en los puertos de Nueva Inglaterra.

1 SHRIMP STATISTICAL DATA PRIOR TO 1955

For the past 14 yr, with the exception of one year (1961), shrimp have been the most valuable species in the commercial fisheries of the United States. During 1966, the dockside (ex-vessel) value of shrimp landed exceeded $95 million and was 43 percent greater than the second most valuable species, Pacific salmon. The value of shrimp landed at ports of the Gulf States (West coast of Florida, Alabama, Mississippi, Louisiana and Texas) has ranged from 83 to 91 percent of the total value of domestic shrimp landings during this same period. A sustained and ever increasing demand for shrimp by consumers has been the major factor in the increased value of shrimp and the increased volume of imports and domestic landings. Increases in domestic catches have been achieved by the discovery of new grounds, more intensive fishing effort on the old grounds, and the development of more efficient fishing craft and gear.

Despite the rapid rise in importance of the shrimp fishery after the second world war, detailed statistics on the fishery were lacking. Generally, statistics were collected showing the total annual shrimp landings in each state, catch by types of gear, and the total craft, fishermen and gear operated in the fishery. Information on processed shrimp products, canned, dried and frozen, also were collected on an annual basis. In many instances, individual state severance tax records were the principal source of data on landings. These annual statistics were supplemented, to a degree, by additional information appearing in daily Fishery Products reports issued by the New Orleans Market News office of the Fish and Wildlife Service, U.S. Department of the Interior. In these releases, during the late forties, there were weekly reports of the predominating size of shrimp landed at a few Gulf ports. Beginning in 1950, annual summaries included information on the species composition of shrimp landed at a few of the major Gulf ports which were given daily Market News coverage. While this type of information was of some benefit to industry, the species and count size composition of shrimp landed at these ports could not, in most instances, be considered representative of the total landings for each of the states.

2 DEVELOPMENT OF THE DETAILED SHRIMP STATISTICAL PROGRAM

In 1955, funds became available within the Department of Interior, Fish and Wildlife Service, for the establishment of a detailed shrimp statistical program, designed to supply information on the Gulf shrimp fishery for economic and biological research, as well as market news for marketing purposes. This program, from its inception, has been supervised by the Branch of Fishery Statistics office in New Orleans, Louisiana.

An analysis of the information to be collected to meet the needs of both industry and government indicated that the assignment of one employee to each major Gulf port would be adequate. There were no specific laws requiring the submittal of the types of information required in our program, but all dealers and fishermen were briefed on the objectives and methods of the program to insure their co-operation. Perhaps a significant factor in the fine co-operation received from industry is the fact that information supplied by dealers and fishermen in co-operative programs is classified as confidential and, as such, cannot be released to other governmental agencies or individuals without a court order.

2.1 Market news

The market news aspects of the new program presented no major problems. Prior to 1955, contract reporters were employed by the Branch of Market News, New Orleans, Louisiana, to collect data on the daily commercial fishery landings at major Gulf ports. The assignment of Bureau Fishery Reporting Specialists to nearly all major Gulf ports not only expanded the coverage of daily commercial fishery landings but also provided much greater detail; thus the species of shrimp and count-size (number of heads-off shrimp per lb) were recorded, as well as prices at those ports which usually control market activity.

For market news purposes, it is not essential that data on shrimp landed at all Gulf ports be published. The essential factor is that representative comparative data on volume, price, variety, size, etc. be available each day, covering landings during the 24 or 48 h period ending that morning. Speed of dissemination and accuracy are perhaps the most important factors in market news, for it is these reports that provide industry with information necessary for short range or day-to-day planning of their operations. At present, the daily Fishery Products reports issued by the New Orleans Market News office are mailed to approximately 1,200 subscribers in the fishing and allied industries in the U.S.A. and foreign countries.

2.2 Economic research

For economic research, both basic and applied, statistics are necessary which translate the quantities of inputs and outputs into values and cost. Our present program supplies only a part of these statistics, primarily information on outputs. Landings data are published monthly and annually in Shrimp Landings bulletins which show the volume and value, by species and count size, of shrimp landed in each of the Gulf and South Atlantic States, as well as the number of trips and count size composition of catches from major grounds fished by the Gulf shrimp fleet. Additional economic data on other major species as well as shrimp are included in Bureau of Commercial Fisheries publications. Among the more important of these publications are monthly and annual Frozen Fishery Products bulletins which provide information on the freezing and cold storage inventories of most major species, quarterly Fish Sticks, Fish Portions, and Breaded Shrimp bulletin, and the annual digest Fishery Statistics of the United States.

It has not been possible to expand our program to include the collection of such information as the costs of fishing and processing operations, capital investment in plants and vessels, and the costs of obtaining capital and the returns to it. This type of information is necessary in developing and testing management plans.

2.3 Biological research

Biological research requires as much detailed information as the previously discussed activities. The catch, by individual fishing craft, by species and by size, the value of the catch, the area and depth of capture, and a measure of the catch per unit of affort are all needed. In our preliminary analysis, it was determined that the use of automatic data processing equipment would be necessary because of the volume and variety of statistical data to be collected and tabulated. Processing in this manner required that a standard form be devised for the recording of data at the ports and also that code systems be established in order that the recorded data could be put into "machine language".

3 ESTABLISHMENT OF CODE SYSTEMS FOR DATA PROCESSING

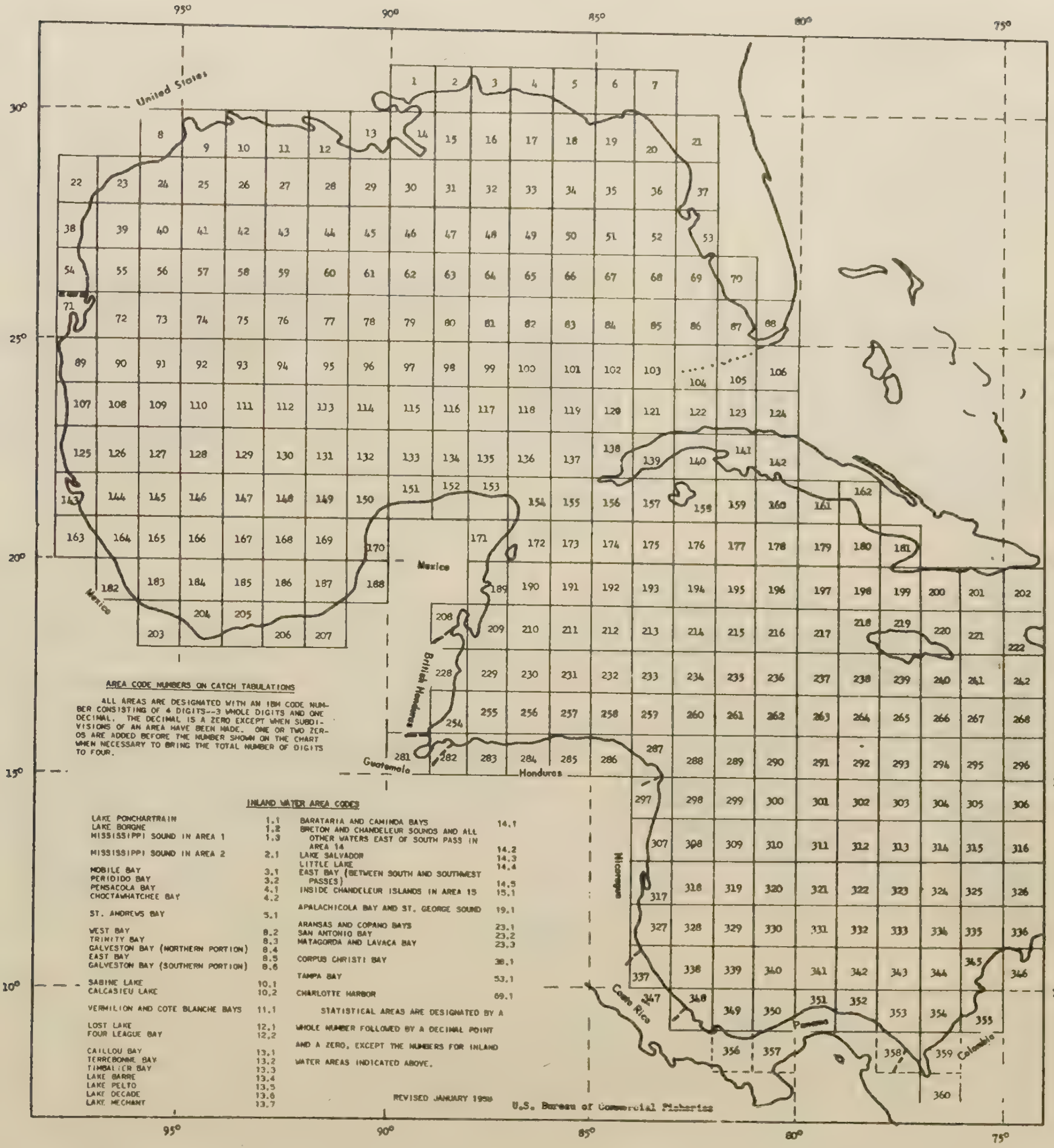
3.1 Fishing grounds

The most difficult coding problem involved the development of a system for recording the areas of the Gulf from which shrimp were taken by fishing craft. For our purposes, the Gulf of Mexico was initially divided into a grid of numbered or statistical units, each of one degree of latitude and longitude (Fig. 1). A two digit code was established for reporting depth fished within the statistical units; since the tabulating of catch for each depth fished would prove too voluminous, depths were coded in 5 fm groupings: 1 to 5 fm as 01, 6 to 10 fm as 02, 11 to 15 fm as 03, etc.

During the latter part of 1958, personnel of the Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas, recommended a revision of the statistical units to facilitate the analysis of Gulf shrimp exploitation data. This recommendation was accepted and the new statistical units (Fig. 2) have been used from 1 January 1959 to the present date. Data coded and tabulated under the original system were readily interchangeable with the new statistical units and there was no loss of comparative data. No changes were made in the system for coding water depths.

GULF OF MEXICO AND WESTERN CARIBBEAN SEA

FWS FISHING GRID ZONES



AREA CODE NUMBERS ON CATCH TABULATIONS

ALL AREAS ARE DESIGNATED WITH AN IBM CODE NUMBER CONSISTING OF 4 DIGITS--3 WHOLE DIGITS AND ONE DECIMAL. THE DECIMAL IS A ZERO EXCEPT WHEN SUBDIVISIONS OF AN AREA HAVE BEEN MADE. ONE OR TWO ZEROS ARE ADDED BEFORE THE NUMBER SHOWN ON THE CHART WHEN NECESSARY TO BRING THE TOTAL NUMBER OF DIGITS TO FOUR.

INLAND WATER AREA CODES

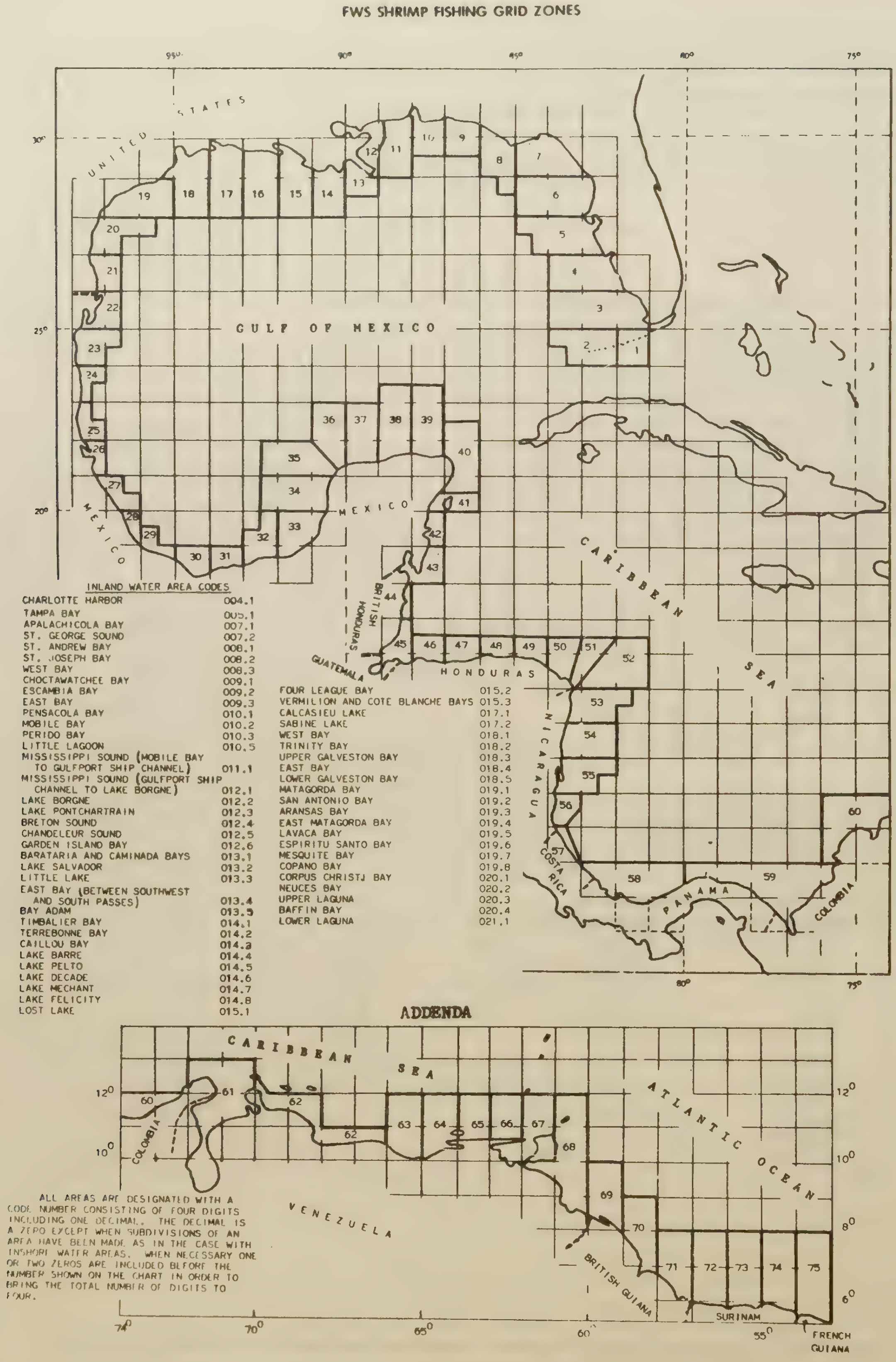
LAKE PONCHARTRAIN	1.1
LAKE BORGNE	1.2
MISSISSIPPI SOUND IN AREA 1	1.3
MISSISSIPPI SOUND IN AREA 2	2.1
MOBILE BAY	3.1
PERIDIDO BAY	3.2
PENSACOLA BAY	4.1
CHOCTAWHATCHEE BAY	4.2
ST. ANDREWS BAY	5.1
WEST BAY	8.2
TRINITY BAY	8.3
GALVESTON BAY (NORTHERN PORTION)	8.4
EAST BAY	8.5
GALVESTON BAY (SOUTHERN PORTION)	8.6
SABINE LAKE	10.1
CALCASIEU LAKE	10.2
VERMILION AND COTE BLANCHE BAYS	11.1
LOST LAKE	12.1
FOUR LEAGUE BAY	12.2
CAILLOU BAY	13.1
TERREBONNE BAY	13.2
TIMBALIER BAY	13.3
LAKE BARRE	13.4
LAKE PELTO	13.5
LAKE DECADE	13.6
LAKE MECHANT	13.7
BARATARIA AND CAMINDA BAYS	14.1
BRETON AND CHANDELEUR SOUNDS AND ALL OTHER WATERS EAST OF SOUTH PASS IN AREA 14	14.2
LAKE SALVADOR	14.3
LITTLE LAKE	14.4
EAST BAY (BETWEEN SOUTH AND SOUTHWEST PASSES)	14.5
INSIDE CHANDELEUR ISLANDS IN AREA 15	15.1
APALACHICOLA BAY AND ST. GEORGE SOUND	19.1
ARANSAS AND COPANO BAYS	23.1
SAN ANTONIO BAY	23.2
MATAGORDA AND LAVACA BAY	23.3
CORPUS CHRISTI BAY	38.1
TAMPA BAY	53.1
CHARLOTTE HARBOR	69.1

STATISTICAL AREAS ARE DESIGNATED BY A WHOLE NUMBER FOLLOWED BY A DECIMAL POINT AND A ZERO, EXCEPT THE NUMBERS FOR INLAND WATER AREAS INDICATED ABOVE.

REVISED JANUARY 1958

U.S. Bureau of Commercial Fisheries

Fig. 1 U.S. Fish and Wildlife Service fishing grid zones in the Gulf of Mexico and western Caribbean Sea, as used in 1958.


FWS SHRIMP FISHING GRID ZONES
95°
90°
85°
80°
75°
30°
25°
20°
15°
10°
UNITED STATES
GULF OF MEXICO
MEXICO
BRITISH HONDURAS
GUATEMALA
HONDURAS
NICARAGUA
COSTA RICA
PANAMA
COLOMBIA
CARIBBEAN SEA
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
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40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
ADDENDA
CARIBBEAN SEA
ATLANTIC OCEAN
VENEZUELA
BRITISH GUIANA
SURINAM
FRENCH GUIANA
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
12°
10°
8°
6°
74°
70°
65°
60°
55°

INLAND WATER AREA CODES

CHARLOTTE HARBOR	004.1
TAMPA BAY	005.1
APALACHICOLA BAY	007.1
ST. GEORGE SOUND	007.2
ST. ANDREW BAY	008.1
ST. JOSEPH BAY	008.2
WEST BAY	008.3
CHOCTAWATCHEE BAY	009.1
ESCAMBIA BAY	009.2
EAST BAY	009.3
PENSACOLA BAY	010.1
MOBILE BAY	010.2
PERIDO BAY	010.3
LITTLE LAGOON	010.5
MISSISSIPPI SOUND (MOBILE BAY TO GULFPORT SHIP CHANNEL)	011.1
MISSISSIPPI SOUND (GULFPORT SHIP CHANNEL TO LAKE BORGNE)	012.1
LAKE BORGNE	012.2
LAKE PONTCHARTRAIN	012.3
BRETON SOUND	012.4
CHANDELEUR SOUND	012.5
GARDEN ISLAND BAY	012.6
BARATARIA AND CAMINADA BAYS	013.1
LAKE SALVADOR	013.2
LITTLE LAKE	013.3
EAST BAY (BETWEEN SOUTHWEST AND SOUTH PASSES)	013.4
BAY ADAM	013.5
TIMBALIER BAY	014.1
TERREBONNE BAY	014.2
CAILLOU BAY	014.3
LAKE BARRE	014.4
LAKE PELTO	014.5
LAKE DECADE	014.6
LAKE MECHANT	014.7
LAKE FELICITY	014.8
LOST LAKE	015.1
FOUR LEAGUE BAY	015.2
VERMILION AND COTE BLANCHE BAYS	015.3
CALCASIEU LAKE	017.1
SABINE LAKE	017.2
WEST BAY	018.1
TRINITY BAY	018.2
UPPER GALVESTON BAY	018.3
EAST BAY	018.4
LOWER GALVESTON BAY	018.5
MATAGORDA BAY	019.1
SAN ANTONIO BAY	019.2
ARANSAS BAY	019.3
EAST MATAGORDA BAY	019.4
LAVACA BAY	019.5
ESPIRITU SANTO BAY	019.6
MESQUITE BAY	019.7
COPANO BAY	019.8
CORPUS CHRISTI BAY	020.1
NEUCES BAY	020.2
UPPER LAGUNA	020.3
BAFFIN BAY	020.4
LOWER LAGUNA	021.1

ALL AREAS ARE DESIGNATED WITH A CODE NUMBER CONSISTING OF FOUR DIGITS INCLUDING ONE DECIMAL. THE DECIMAL IS A ZERO EXCEPT WHEN SUBDIVISIONS OF AN AREA HAVE BEEN MADE AS IN THE CASE WITH INSHORE WATER AREAS. WHEN NECESSARY ONE OR TWO ZEROS ARE INCLUDED BEFORE THE NUMBER SHOWN ON THE CHART IN ORDER TO BRING THE TOTAL NUMBER OF DIGITS TO FOUR.

Fig. 2 U.S. Fish and Wildlife Service shrimp fishery grid zones in the Gulf of Mexico and Caribbean Sea, adopted in January 1959.

3.2 Fishing vessels

Compiling data on the catches of individual boats required a numbering system for the boats. Originally, a complete alphabetical listing was made of all craft in the Gulf shrimp fishery; craft were then assigned 5 digit numbers, beginning with 00005, with sufficient spacing between numbers to permit the inclusion of new craft entering the fishery in their proper alphabetical position. Employees at all ports were furnished copies of this listing, known as the Shrimp Vessel Code Book, and were informed of additions, deletions, change of name of vessels, etc., through periodic memoranda issued by the New Orleans office. Beginning in 1961, the official number assigned to vessels (craft of 5 net tons and over) when they were documented by the Bureau of Customs, U.S. Treasury Department, was used for identification. This simplified the preparation of vessel code books and resulted in more accurate reporting. Information on physical characteristics (length, tonnage, horsepower, year built), size of crew, and quantity of gear for individual vessels, identified by name or official number, appear on cards maintained in our data processing system. The use of the official number rather than an arbitrarily assigned number facilitates correlation of catch data with any of these characteristics should the need arise.

3.3 Count size grading and type of landing

Research biologists also requested information on the method by which shrimp are graded for size by dealers, and the condition (heads-on or heads-off) in which shrimp were landed. Data on shrimp graded by the dealer (from random samples taken during unloading, known as "box" weight) are assigned code number "1"; shrimp graded by machine are assigned code number "2". Code numbers established for the condition of shrimp landed (appearing as "type landing" on our forms) were "1" for heads-on landings, "2" for heads-off, and "3" for landings consisting of both heads-on and heads-off shrimp.

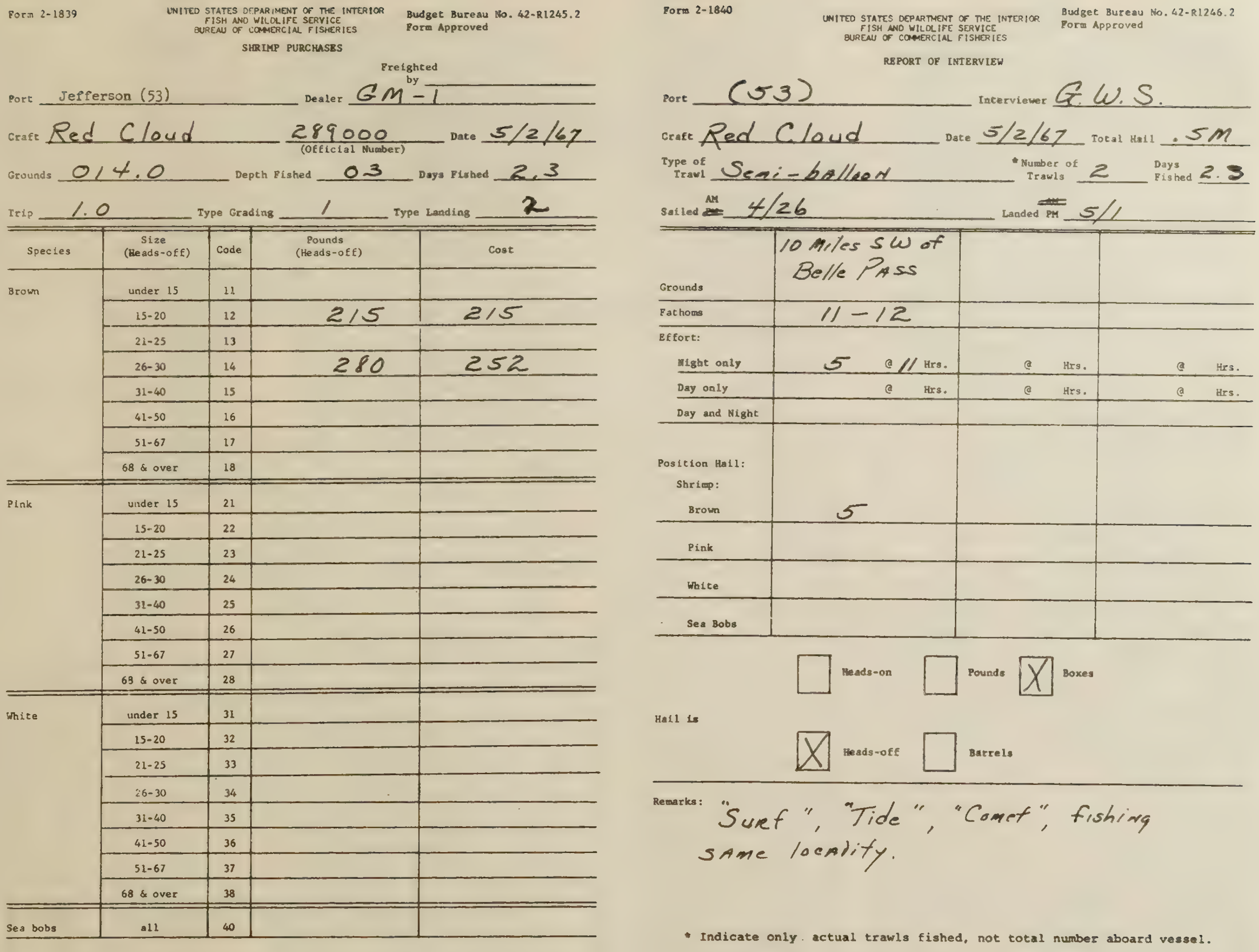
4 RECORDING OF POUNDAGE AND VALUE

The fact that some shrimp are landed with heads-on and others with heads-off presented a minor problem. While the ideal solution would perhaps have been to record the weight actually landed (heads-on or heads-off), it was felt that this would add appreciably to the volume of data to be published, and, in some instances, prove confusing. It was decided that, since the majority of shrimp were landed in a heads-off condition, our reports, with the exception of the annual _Fishery Statistics of the United States_, would list landings as heads-off weight (in lb). This, of course, required the use of conversion factors in instances where shrimp are landed with heads on. Prior to 1962, a factor of 1.68 was used for all species, but research indicated that this factor was not accurate (Kutkuhn, 1962). Beginning 1 January 1962, the following factors were used: brown shrimp (_Penaeus aztecus_), 1.61; pink (_P. duorarum_ and _P. brasiliensis_), 1.60; white, (_P. setiferus_), 1.54; seabob (_Xiphopenaeus kroyeri_), 1.53; and royal red (_Hymenopenaeus robustus_), 1.80.

The ex-vessel or dockside value of shrimp caught by fishing craft also presented a minor problem. At some Gulf ports there is a practice of charging the vessel for unloading and weighing of catches, by imposing a fixed charge, not related directly to the quantity of shrimp landed by the individual vessel. Such deductions from the gross amount received by the fishing craft are recorded to insure the comparability of ex-vessel value, regardless of the port at which shrimp are landed.

5 COLLECTION OF DATA

The method of collecting data is similar at all Gulf ports. Each working day, Fishery Reporting Specialists obtain the volume and value, by individual vessel, of shrimp purchased by each dealer the previous day. Data are recorded on Form 2-1839 (Fig. 3) commonly known as a "shrimp schedule" by our staff. The quantity of shrimp landed daily at each port, by species and count size, is required for market news purposes, and the Fishery Reporting Specialist tabulates the data from shrimp schedules and transmits it to the New Orleans office by telephone. While a shrimp schedule is



Form 2-1839

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES

Budget Bureau No. 42-R1245.2
Form Approved

SHRIMP PURCHASES

Port Jefferson (53) Dealer GM-1 Freighted by ______

Craft Red Cloud 289000 (Official Number) Date 5/2/67

Grounds 014.0 Depth Fished 03 Days Fished 2.3

Trip 1.0 Type Grading 1 Type Landing 2

Species	Size (Heads-off)	Code	Pounds (Heads-off)	Cost
Brown	under 15	11		
	15-20	12	215	215
	21-25	13		
	26-30	14	280	252
	31-40	15		
	41-50	16		
	51-67	17		
	68 & over	18		
Pink	under 15	21		
	15-20	22		
	21-25	23		
	26-30	24		
	31-40	25		
	41-50	26		
	51-67	27		
	68 & over	28		
White	under 15	31		
	15-20	32		
	21-25	33		
	26-30	34		
	31-40	35		
	41-50	36		
	51-67	37		
	68 & over	38		
Sea bobs	all	40		

Form 2-1840

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES

Budget Bureau No. 42-R1246.2
Form Approved

REPORT OF INTERVIEW

Port (53) Interviewer G. W. S.

Craft Red Cloud Date 5/2/67 Total Hail .5M

Type of Trawl Semi-balloon *Number of Trawls 2 Days Fished 2.3

Sailed AM ~~PM~~ 4/26 Landed ~~AM~~ PM 5/1

Grounds	10 Miles SW of Belle Pass		
Fathoms	11-12		
Effort:			
Night only	5 @ 11 Hrs.	@ Hrs.	@ Hrs.
Day only	@ Hrs.	@ Hrs.	@ Hrs.
Day and Night			
Position Hail: Shrimp: Brown	5		
Pink			
White			
Sea Bobs			

Hail is ☐ Heads-on ☐ Pounds ☒ Boxes

☒ Heads-off ☐ Barrels

Remarks: "Surf", "Tide", "Comet", fishing same locality.

* Indicate only actual trawls fished, not total number aboard vessel.

Fig. 3 Shrimp schedule, used by port agents for Gulf of Mexico shrimp landings.

prepared for the landings of each and every trip, the same procedure is not used for shrimp landed by 'boats' (craft of less than 5 net tons). These boats usually confine their fishing to inside waters, and during the shrimp season in Louisiana they frequently make two trips per day, each day of the week. Data on catches by boats are consolidated, with a shrimp schedule prepared for each statistical unit fished by the fleet. In place of the vessel name on the shrimp schedule, the total number of boats whose catches have been included on the schedule is inserted.

6 INTERVIEWING

Each day, the Fishery Reporting Specialist also interviews captains of as many newly arrived shrimp vessels as possible, obtaining from them information on the grounds fished, effort expended, and other information as required to complete Form 2-1840 (Fig. 3). Form 2-1840 is printed on the reverse of Form 2-1839 so that interview data may be directly correlated with the actual volume and value of shrimp landed by the vessel, as obtained from dealer records. Form 2-1839 is the source document for the preparation of data processing cards, and the items appearing at the top of the form are coded for this purpose. The example of a completed form (Fig. 3) indicates the way the coding is accomplished in accordance with information obtained by interview with the captain of the vessel.

The value of catch data depends almost entirely on the care with which information on the grounds fished and fishing effort expended is obtained from the captain of each vessel. With as many as 300 vessels operating out of one port at the peak of a season, complete interview coverage cannot be obtained for all landings. The grounds and depth fished for non-interviewed trips are, in part, estimated by Fishery Reporting Specialists, using several sources of information; dealers unloading the catch of vessels often know the grounds from which the shrimp were taken by a specific vessel; at the time of interviewing a vessel captain, the names of other vessels fishing the same locality are obtained. Some of our Fishery Reporting Specialists also monitor marine radio band to obtain information as to where vessels are fishing, and conversation between vessel captains on this band often includes a discussion of catch rates.

7 FISHING EFFORT

In our program, days fished, based upon a 24-h day, was selected as the effort factor. This is obtained by calculating the total hours of fishing, as reported during the interview, and dividing by 24; the result is expressed to the first decimal place. Hours fished, as reported during the interview, represent the elapsed time from the setting of the trawl each day until it is hauled back aboard the vessel after the final tow. When catches are taken from more than one statistical unit during a trip, effort and catch data are apportioned between areas as indicated in the interview.

8 PROCESSING AND PUBLICATION OF DATA

At the end of each month, Fishery Reporting Specialists mail all completed Forms 2-1839 and 2-1840 to the Branch of Fishery Statistics office in Arlington, Virginia, where the automatic data processing is accomplished. After processing, the data are published in monthly and annual Gulf Coast Shrimp Data bulletins which are used primarily by biologists engaged in shrimp research. These bulletins contain two major tabulations. The first consists of data on the total shrimp catch (interview and non-interview) landed at Gulf ports, giving the species and size, by statistical unit, depth and number of trips. The second table consists of data for interviewed craft only and contains days fished and species and size of shrimp, by area, depth, and number of trips.

All data processing cards, as well as the original source documents (shrimp schedules), are sent to the Bureau's Galveston Biological Laboratory for storage. Data are thus readily available for processing should the need arise for information not currently tabulated in the present program.

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E/55

OXYGEN CONSUMPTION OF THE PRAWNS *Penaeus indicus* H. MILNE EDWARDS AND *Penaeus semisulcatus* DE HAAN

by

M.N. KUTTY [1]
Central Marine Fisheries Research Institute
Mandapam Camp, India

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Abstract

The routine oxygen consumption of *Penaeus indicus* and *Penaeus semisulcatus* (acclimation and test in seawater at 30°C), starved for 5-10 days, declined sharply by about the second day of starvation, and no marked change from the reduced rate was observed during the subsequent days of starvation in either species. The reduced level of metabolism attained due to starvation was 0.404 mg/g/h, being 32 percent less than the metabolic rate for the first day of starvation in the case of *P. indicus*, whereas the corresponding values for *P. semisulcatus* were 0.151 mg/g/h and 57 percent. When the amount of available dissolved oxygen is the same, *P. indicus* and *P. semisulcatus* starved for two days or over can be expected to survive for 1.7 and 2.3 times as long, respectively, as those not starved, under the conditions of the present tests.

The present regression of log oxygen consumption on log weight in *P. indicus* has a slope of 0.501. While the highest routine metabolic rate of *P. indicus* declined with the decrease in ambient oxygen concentration, such oxygen dependence need not be exhibited in all cases. There is possibly an increase in the standard metabolic rate of *P. indicus* at an oxygen level of 1-2 ppm when the prawns are allowed to bring down the ambient oxygen concentration by their own respiration.

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E/55

CONSOMMATION D'OXYGENE DES CREVETTES Penaeus indicus H. MILNE EDWARDS ET Penaeus semisulcatus DE HAAN

Résumé

La consommation normale d'oxygène de Penaeus indicus et de Penaeus semisulcatus (acclimatation et épreuve en eau de mer à 30°C) privés de nourriture pendant 5 à 10 jours a nettement diminué à partir du deuxième jour environ, et n'a plus accusé de modification marquée pendant les jours suivants. Le niveau réduit du métabolisme causé par le jeûne (0,404/mg/g/h) était inférieur de 32 p. 100 à celui du premier jour de jeûne dans le cas de P. indicus, les valeurs correspondantes chez P. semisulcatus étant de 0,151 mg/g/h et de 57 p. 100. Lorsque la quantité d'oxygène dissous disponible est la même, on peut s'attendre à ce que P. indicus et P. semisulcatus à jeun pendant deux jours ou plus présentent un taux de survie représentant respectivement 1,7 et 2,3 fois celui des animaux non privés de nourriture, dans les conditions des expériences rapportées.

La courbe actuelle de régression de la consommation d'oxygène (log) par rapport au poids (log) chez P. indicus accuse une pente de 0,501. Si le métabolisme normal plus élevé de P. indicus a diminué avec la teneur en oxygène du milieu cette sujétion n'apparaîtra pas nécessairement dans tous les cas. Il se peut que le taux métabolique normal de P. indicus s'accroisse pour une teneur en oxygène de 1-2 parties par million lorsque les crevettes font baisser la concentration ambiante en oxygène par leur respiration.

EL CONSUMO DE OXIGENO DE LOS LANGOSTINOS Penaeus indicus H. MILNE EDWARDS Y Penaeus semisulcatus DE HAAN

Extracto

El consumo normal de oxígeno de Penaeus indicus y P. semisulcatus (aclimatación y ensayo en agua de mar a 30°C), mantenidos sin alimentar de 5 a 10 días, disminuyó bruscamente al segundo día de la prueba, no observándose en ambas especies durante los días siguientes a ésta ningun marcado cambio en relación con la reducida tasa. El reducido nivel de metabolismo obtenido debido al hambre a que se sometieron fue de 0,404 mg/g/h, siendo un 32 por ciento inferior a la tasa metabólica en el primer día de hambre en el caso de P. indicus, mientras que los valores correspondientes para P. semisulcatus fueron de 0,151 mg/g/h y 57 por ciento. Cuando la cantidad de oxígeno disuelto existente es la misma, P. indicus y P. semisulcatus, mantenidos sin comer durante dos días o más, pueden sobrevivir 1,7 y 2,3 veces más, respectivamente, que los que no se mantuvieron sin comer, dentro de las condiciones de los actuales ensayos.

La actual regresión del consumo logarítmico de oxígeno en relación con el peso logarítmico del P. indicus tiene una pendiente de 0.501. Aunque descendió la elevada tasa normal metabólica de P. indicus al disminuir la concentración del oxígeno en el ambiente, tal dependencia del oxígeno no era preciso que existiera en todos los casos. Posiblemente existe un aumento de la tasa metabólica normal de P. indicus a un nivel de oxígeno de 1 - 2 p.p.m. cuando se deja a los langostinos que hagan descender la concentración del oxígeno del ambiente con su respiración.

1 INTRODUCTION

Studies on the oxygen consumption of animals of economic value are of special interest since, as well-recognized, an estimate of the energy requirements of an animal can usually be obtained from measurements of its oxygen consumption in an aerobic state. Though the respiratory physiology, especially with reference to oxygen consumption, has been studied extensively in the case of fishes (review by Fry, 1957), only a few workers have paid attention to oxygen consumption in prawns (review by Wolvekamp and Waterman, 1960). Rao (1958) and Subrahmanyam (1962) have made recent studies in this field in India. Whereas the influence of weight and ambient oxygen concentration on the oxygen consumption of Penaeus indicus have been studied by Subrahmanyam (1962), the oxygen consumption of Penaeus semisulcatus has not previously been investigated. There is no study, as it appears, on the influence of starvation on the respiration of crustaceans, even though it is known that a marked reduction in oxygen consumption takes place due to starvation in some other poikilotherms (Berg, Lumbye and Ocklemann, 1958; Mann, 1958; Saunders, 1963; Beamish, 1964a).

The present study provides information on the influence of starvation on the metabolism of P. indicus and P. semisulcatus and also supplements information already available on the influence of weight and ambient oxygen concentration on the respiration of P. indicus.

2 MATERIAL AND METHODS

P. indicus (juveniles) used in the present study were caught at Pullamadam from a brackishwater creek opening into Palk Bay. Larger P. indicus (adults) were taken from a large concrete stocking tank in the marine aquarium of the Central Marine Fisheries Research Institute. The adults were used only for studying the influence of weight and ambient oxygen on metabolism. The experiments designed to study the influence of starvation on the oxygen consumption of adult P. indicus had to be abandoned due to some unforseen difficulties. Only adults of P. semisulcatus were used in the present study. They were caught in an Indo-Norwegian project trawler fishing off Mandapam. The expermental animals were kept in running sea-water of an average salinity of 36.5°/oo and an average temperature of 30°C for at least two weeks before they were used in experiments. The oxygen concentrations of the water in the acclimation tanks were close to air saturation. The animals undergoing acclimation were exposed to normal daylight. During the acclimation period the prawns were fed with chopped clam meat (Donax spp.) once daily, as much as they would eat. The prawns held on to the clam meat with their pereiopods for several hours and ate avidly. The remains of the food were removed about 6 hours after it was supplied.

Experiments were conducted at the same level of salinity and temperature to which the prawns were acclimated. Oxygen concentrations during tests declined from near air saturation to about 70 percent air saturation, except in the experiments in which the influence of ambient oxygen on the metabolism was studied, in which case the ambient oxygen concentration in the respirometers was allowed to be reduced by the respiration of the animals themselves until close to the asphyxial level. All the tests were done in the afternoons.

The smaller prawns (juveniles) were kept one each in 400 ml conical flasks and the larger prawns in similar flasks of 1000 ml capacity; these flasks (respirometers) remained submerged in sea water inside a 'metabolism chamber' (Job, 1955, 1959), which is a wooden box with galvanised iron sheeting inside, the inner walls of the iron sheeting and the wooden lid being painted black. Water entered the box through an inlet on one side and overflowed through an outlet on the opposite side, maintaining a constant level of water over the respirometers. Each respirometer with the experimental animal inside was arranged as shown in Fig. 1. The arrangement was such that water flowed through the respirometers for extended periods without any apparent harm to the animals, and therefore experiments lasting for several days could be conducted without disturbing the animals. Animals under test were not fed. Water continued to flow through the

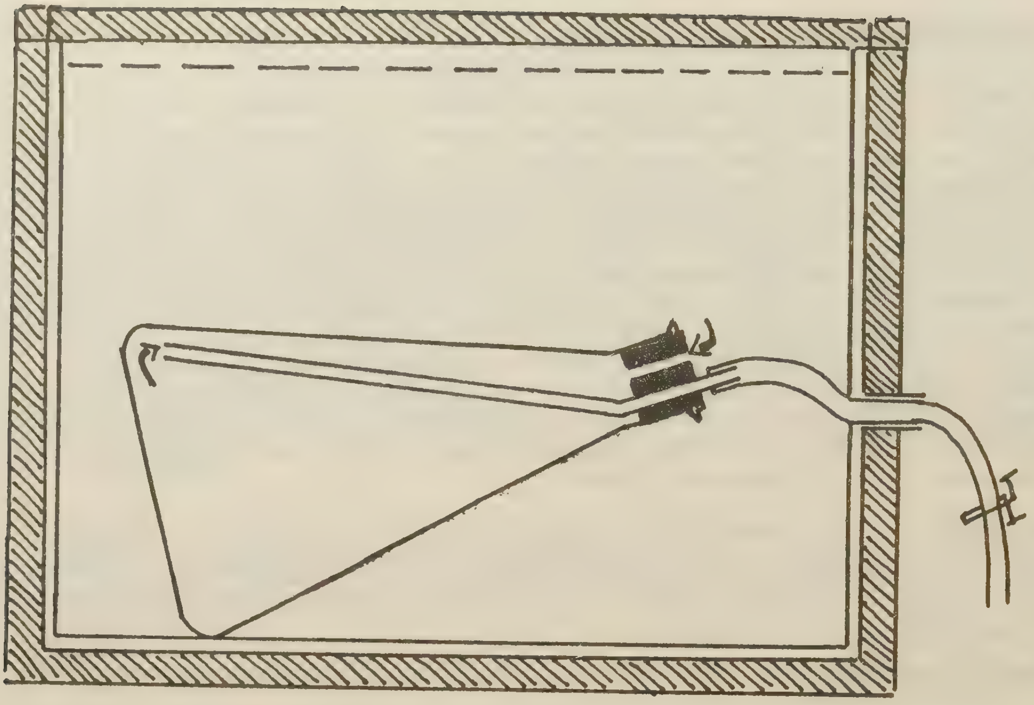

Fig. 1 Schematic section through a single unit of respirometer assembly (Job's apparatus). The broken horizontal line above shows the level of water. The arrows indicate the direction of flow of water when the outlet tube from the respirometer is kept open. The walls of the chamber are of wood (hatched area) with galvanized iron sheeting inside. The level of water is maintained by a constant level device at one end of the box (not shown). Water enters from the end of the chamber opposite to the overflow.

respirometers throughout the period of the experiment, except during the short intervals when the outlets of the respirometers were closed once a day for the determination of metabolic rate.

Dissolved oxygen concentrations were measured by using standard Winkler techniques on 20 ml water samples.

2.1 Experimental procedure

The prawns were starved for about 18 h in their acclimation tanks, after which they were removed for weighing. The adhering water on each prawn was carefully removed with a dry towel and filter paper, and then it was put inside a weighed tube about half-full with sea water which just accommodated the animal. After weighing, one prawn was put in each respirometer. The box with the respirometers inside was closed, and after sea water had flowed through the respirometers for 2 to 2½ h, i.e. about 20 h after the animals were last fed, a water sample was taken for oxygen determination and flow through the respirometer was then stopped by clamping the outlet tube. After a measured interval (15 or 20 min unless otherwise stated) a second water sample was taken, then the flow through the respirometer was resumed. The metabolic rate of the prawn was calculated from the oxygen concentrations of the two samples. This sampling procedure was repeated at 24 h intervals. The animals were weighed again at the end of the experiment.

It may be pointed out that the rate of oxygen consumption of each prawn was determined only once a day, except in experiments where the influence of ambient oxygen was studied. External disturbances to the animals were avoided as far as possible. The chamber was normally opened only once a day, after the metabolic rates for the day were measured, to check the state of the animals. The measurements of oxygen consumption made under such conditions can be termed as the 'routine metabolic rate' (Job, 1955; Fry, 1957) in that the only activity of the animals under test was spontaneous.

In the case of P. indicus, one extra series of tests was performed in which the prawns were handled every day, as indicated below. In this respect the experimental procedure of the latter series differed from the one described above. On each day the respirometers were removed from the experimental assembly. Subsequently the prawns were taken out by hand, kept for a few minutes in a bucket of sea water and put back again into the respirometers, which were then reassembled as in the original set-up. Each day, the metabolic rate was determined 2 to 2½ after the prawns were handled. The latter series of tests was designed as a supplement to the earlier series, to distinguish, if possible, the influences of starvation and handling on the oxygen consumption of the prawns under study.

The experiments dealing with the influence of ambient oxygen were done on adult P. indicus starved for three days inside the experimental assembly described above. During the tests the respirometers remained closed and water samples for oxygen analyses were taken at intervals of 15 to 30 min until the asphyxial levels of the animals were reached.

3 RESULTS AND DISCUSSION

3.1 Influence of starvation

3.1.1 Penaeus indicus Table I gives the mean rates of oxygen consumption of starved P. indicus at intervals up to the 10th day. It should be noted that the metabolic rate indicated for the first day of starvation was estimated after the prawns had been starved for about 20 h. As shown in Table I, the mean metabolic rate for the first day (0.695 mg/g/h) was much higher than the means of the rates for each of the subsequent days. This feature is clearly shown in Fig. 2, where the mean rates (closed circles) for each day of starvation are plotted. By about the 2nd day of starvation the metabolic rate declined sharply, and further starvation did not cause any marked change from this reduced level. The mean oxygen consumption calculated from all values determined for the 2nd to the 10th day was found to be 0.404 mg/g/h, indicating a reduction of about 32 percent in the metabolic rate from that of the first day.

Results of experiments of P. indicus 'handled' every day (see section 2.1) are presented in Table II. The metabolic rates of oxygen consumption of this group are also plotted in Fig. 2 (open circles). The metabolic rate for the first day is slightly higher than the corresponding value in the first series of experiments. The general trend in the decline of oxygen consumption is markedly similar in both series, as is suggested by the trend line (thick line) drawn considering all the points shown in Fig. 2. A comparison of the mean rates of metabolism presented in Tables I and II indicates negligible differences between the values obtained from prawns which were handled on the first day only and those which were handled on every day of the experimental period. Enhanced metabolism due to handling has been noted in other animals (Winberg, 1956; Fry, 1957). It is possible, however, that in the case of the prawns which were handled daily any enhanced metabolism may have subsided to pre-handling levels within the course of the 2 to 2½ h which elapsed between the actual period of handling and the tests. The results obtained suggest that the metabolic rates of prawns determined in the present study are not influenced significantly by handling.

3.1.2 Penaeus semisulcatus Results of experiments on P. semisulcatus are summarized and presented in Table III. Here again by about the second day of starvation the metabolic rate had declined markedly and stayed at about the same level until the last day of the experimental period (6th day) (see Fig. 3). The mean metabolic rate for the first day was 0.346 mg/g/h, and the mean of all the rates from the second to the last day (6th) of the experiment showed a reduction of about 57 percent from the former. It may

TABLE I

Influence of starvation on the oxygen consumption of *Penaeus indicus* (2.70 ± 0.28 g : mean ± one S.E.: n = 4) acclimated to 30°C in sea water (36.5 permille salinity) and tested at the same levels of temperature and salinity

Day of starvation	Oxygen consumption in mg/g/h (mean ± one S.E.)	Number of determinations
1st day	0.695 ±0.109	3
2nd day	0.384 ±0.028	3
3rd day	0.458 ±0.094	4
4th day	0.406 ±0.045	4
5th day	0.487 ±0.234	3
8th day	0.278 ±0.064	4
10th day	0.450 ±0.146	2

TABLE II

Influence of starvation on the oxygen consumption of *Penaeus indicus* (3.99 ± 1.16 g : mean ± one S.E.: n = 4) 'Handled' (see text) daily prior to the determination of the rates of oxygen consumption. The conditions of acclimation and test are similar to those indicated in the explanation for Table I

Day of starvation	Oxygen consumption in mg/g/h (mean ± one S.E.)	Number of determinations
1st day	0.783 ±0.117	4
2nd day	0.399 ±0.080	4
3rd day	0.500 ±0.216	4
4th day	0.384 ±0.077	4
5th day	0.344 ±0.113	4

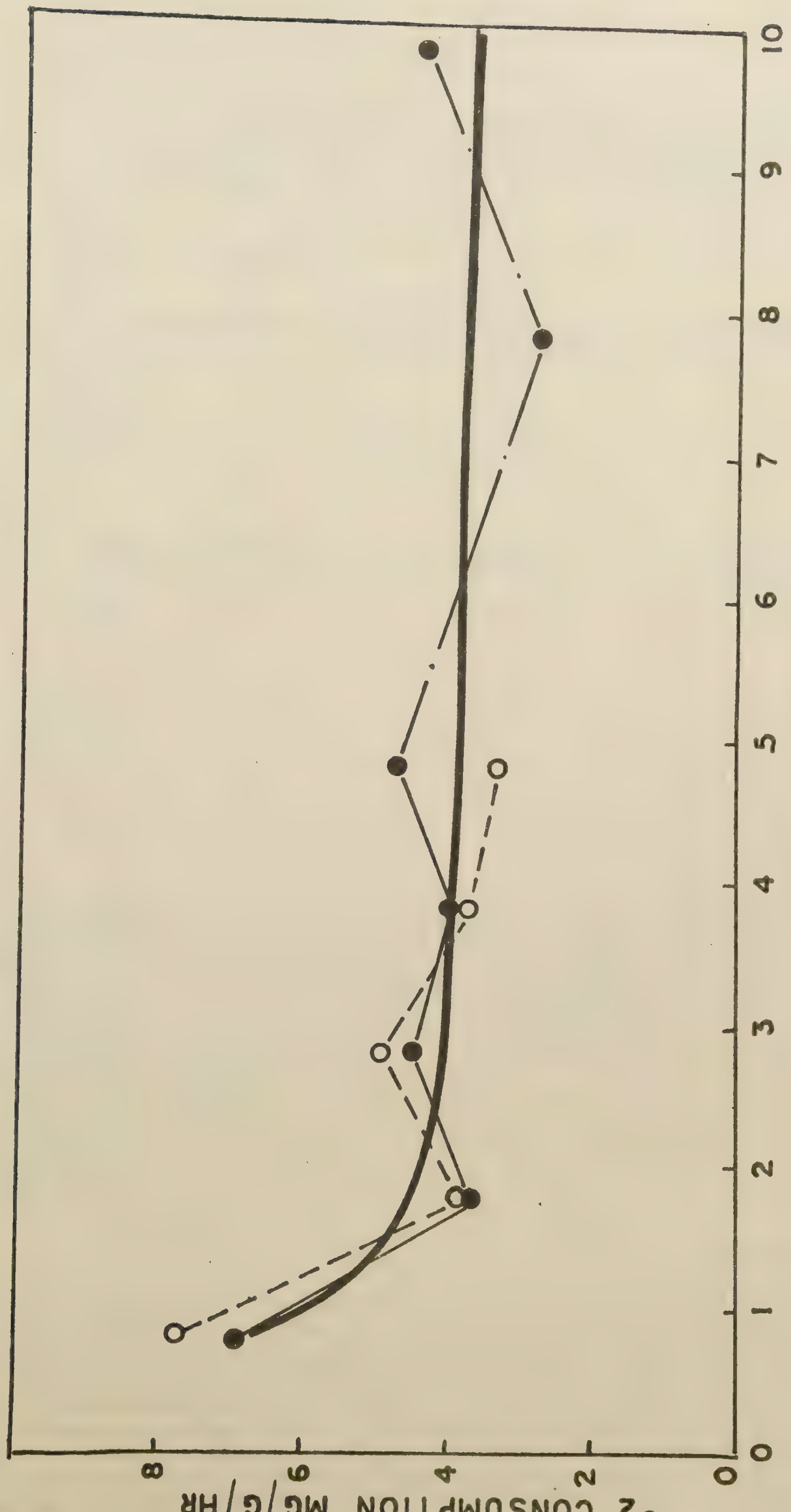

Fig. 2 Oxygen consumption in relation to period of starvation in *Penaeus indicus* in sea water at 30 C. The closed circles are mean values (taken from Table I) of metabolic rates of prawns 'handled' only on the first day of the experiment, and the open circles, denote similar values (taken from Table II) from prawns 'handled' on every day of the experiment (see text for details). The trend (thick) line is drawn by eye.

TABLE III

Influence of starvation on the oxygen consumption of Penaeus semisulcatus (17.39 ± 0.93 g : mean ± one S.E. : n = 4) acclimated and tested under similar conditions as those indicated in the explanation for Table I

Day of starvation	Oxygen consumption in mg/g/h (mean ± one S.E.)	Number of determinations
1st day	0.346 ±0.070	3
2nd day	0.161 ±0.019	4
3rd day	0.111 ±0.007	3
4th day	0.179 ±0.040	4
5th day	0.153 ±0.034	2
6th day	0.132 ±0.008	2

be noted that the relative decrease in the metabolic rate is more than that found for P. indicus. The metabolic rate of P. semisulcatus determined after the first day of starvation shows less variation from the steady level than in the case of P. indicus. As pointed out earlier, the individuals of P. semisulcatus tested were adults and larger forms, whereas those of P. indicus were juveniles. These differences may also be due to the quieter nature of P. semisulcatus, which were often seen to bury themselves in the sand in the acclimation tanks and, if sand were provided, inside the respirometers (see below section 3.4). The juveniles of P. indicus did not show this tendency during the several months of observation. Much of the difference in the metabolic rates of the two species may be attributed to the differences in their weights (Subrahmanyam, 1962), but species differences, and the fact that the salinities of the natural environments from which they were collected differ markedly, cannot be ignored (Lofts, 1956).

3.2 Influence of weight

As indicated earlier, the influence of weight was studied in P. indicus only. The results obtained are presented in Fig. 4 (closed circles). The regression line calculated for the values has a slope of 0.501, as against the 'b' value of 0.604 obtained by Subrahmanyam (1962) for P. indicus at 14 to 15°/oo salinity and 28°C. A combined plot of the present values and those obtained by Subrahmanyam (1962) (open circles) in Fig. 4, shows that the points intermingle; it does not suggest such a difference in the scatter values as the difference in slope values indicate. It is evident that the present values apply to larger animals mainly. The difference in salinity levels of the two sets of experiments may explain the difference in the slopes

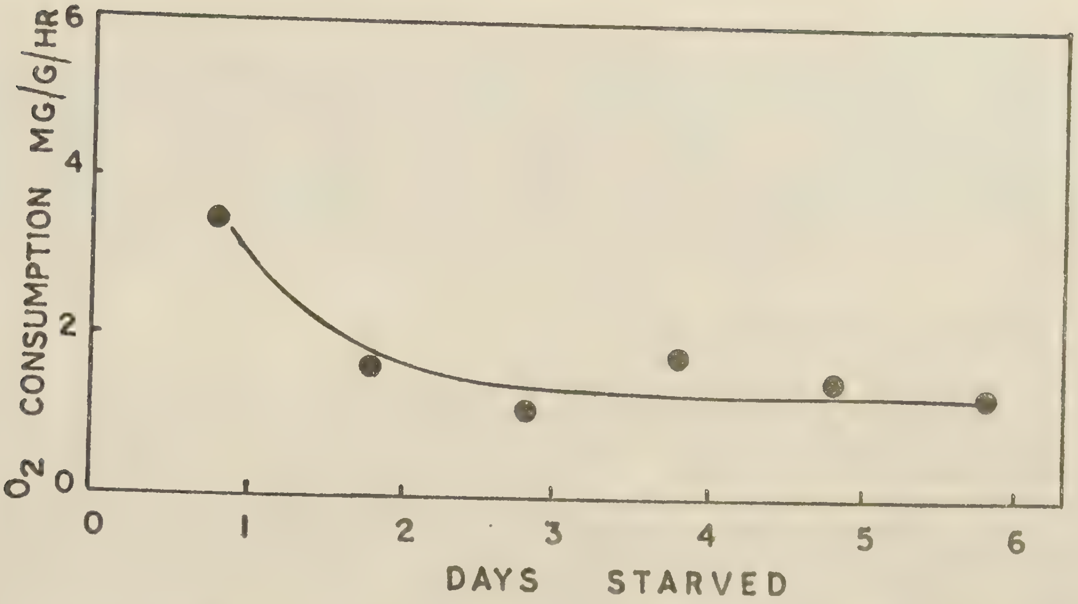

Fig. 3 Oxygen consumption in relation to period of starvation in Penaeus semisulcatus in sea water at 30°C. Mean values of metabolic rates from Table III are plotted.

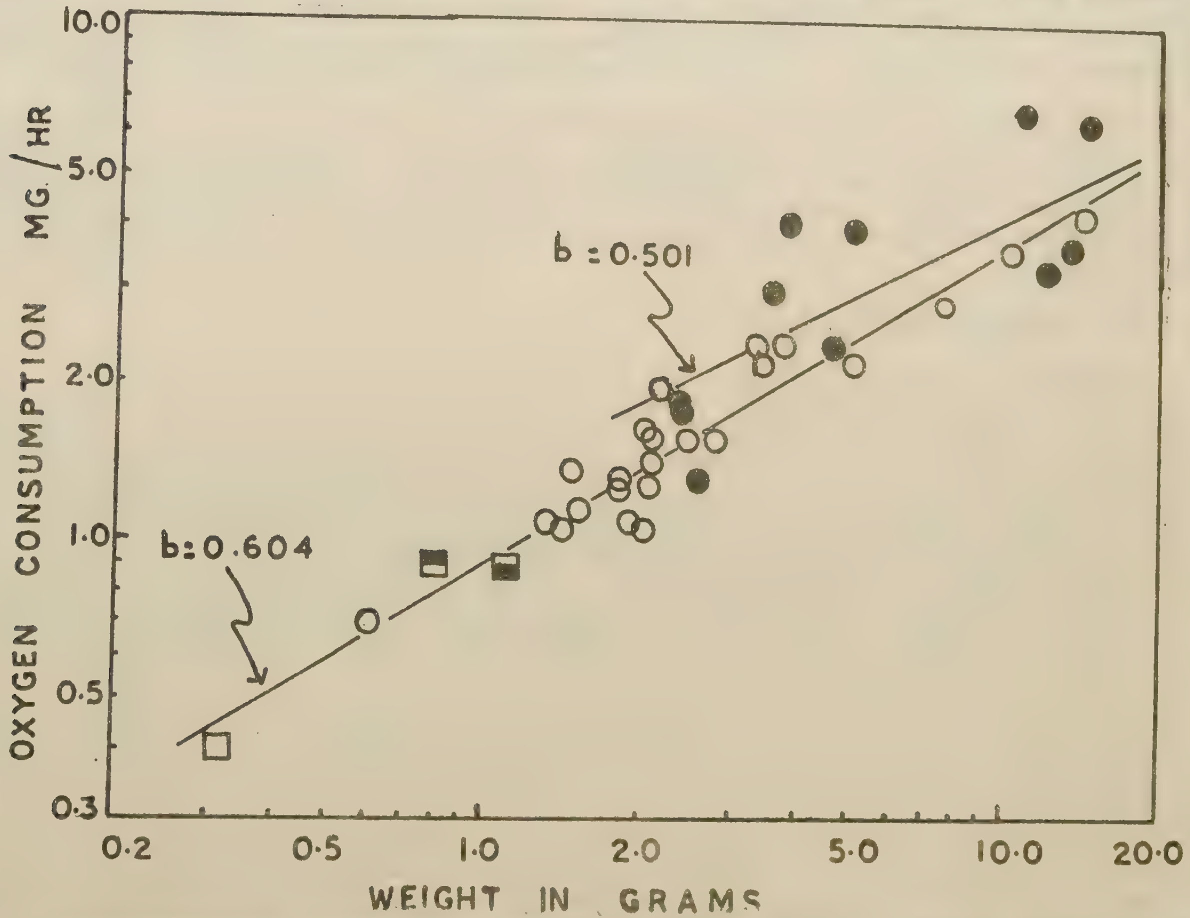

Fig. 4 Oxygen consumption in relation to weight in Penaeus indicus. Present values are shown as closed circles. The open circles are plotted from results obtained by Subrahmanyam (1962) on P. indicus at 28.2°C and 14°/oo (salinity); the three large squares indicate values obtained (Kutty, MS) from small P. indicus acclimated to to and tested at the same temp (29°C) and the same 3 levels of salinities (35°/oo, large open square; 21°/oo, square-upper half closed; 7°/oo, square-lower half closed). Each square represents a mean of 3 to 8 determinations, for accommodation of which in the graph both 'X' and 'Y' values are multiplied by a factor of 10.

of the regression lines, but no definite conclusion can be reached from the limited data available. Data obtained in another series of experiments (Kutty, MS) are also plotted (squares) in Fig. 4. These points represent means of 3 to 8 values of metabolic rates of much smaller prawns (see legend for Fig. 4) acclimated to three different salinities and tested at the same three salinities. The influence of salinity on the metabolic rates of P. indicus will be discussed elsewhere, but it appears that all the points shown in Fig. 4 form part of a single scatter in spite of the differences in salinity in the different tests.

3.3 Influence of ambient oxygen

These experiments were also done with P. indicus only. Results obtained from four separate series of runs performed simultaneously are shown in Fig. 5. Data from the four animals used are indicated separately in the figure. A curve is drawn connecting the highest rates obtained. The lowest rates have also been connected similarly. The shape of the curve through the highest routine rates appears to be similar to the metabolic rate - ambient oxygen curves obtained for P. indicus by Subrahmanyam (1962), whereas the values other than the highest, which were obtained during the same test period, do not indicate such marked oxygen-dependence. This feature suggests that these animals kept undisturbed under standard conditions may have exhibited different levels of spontaneous activity (Beamish and Mookherjii, 1964), which, as stressed by Fry (1947, 1957), is a factor of prime importance in metabolism studies. In studies reported earlier, uniformly high rates have been obtained which show clearly the oxygen-dependence of metabolism, but these animals were probably under some stimulus causing excitement and activity, which induced them to respire at near maximum levels.

The line drawn through the lowest values in Fig. 5 can be taken as the closest to the standard metabolic rate of P. indicus. It may be pointed out that the rise shown in the latter curve at the low ambient oxygen level of 1 to 2 ppm is possibly indicative of an increase in the 'standard metabolism' of the prawn. A similar rise in the standard metabolism below the critical oxygen level has been observed in certain fishes by Beamish (1964b).

3.4 General considerations

Decrease in oxygen consumption in consequence of partial starvation was reported in the limpet Ancylus fluviatilis by Berg, Lumbye and Ocklemann, (1958). Mann (1958) observed that, after a meal of Tubifex, oxygen consumption of the leach Erpobdella testacea increased three-fold and declined to the previous level over a period of 4 days. Saunders (1963) noted that the oxygen consumption of cod decreased gradually during starvation for about a week. In the above studies the oxygen consumption refers to the routine metabolic rate only, and in estimating metabolic rates no account was taken of the spontaneous activity of the animals. The close relation between the metabolic rate and activity has already been indicated with reference to the influence of ambient oxygen on the metabolic rate. In his studies with speckled trout (Salvelinus fontinalis) and white sucker (Catostomus commersoni) Beamish (1964a) used an apparatus which could take account of spontaneous activity and obtained extrapolated values of standard metabolism of these fishes. He observed that there was a steep decline in the standard oxygen consumption of the trout and white sucker to reach a steady level by about the second day, which was maintained for 10 to 25 days. Simultaneous measurements of routine metabolic rates of these fishes, however, showed a gradual decline due to starvation, as observed in other animals by earlier workers. Beamish suggested that the reduction in the routine metabolic rates over the period of starvation was mainly due to a decline in spontaneous activity, whereas the decline in standard rate reflected an actual reduction in oxygen consumption due to starvation.

In the present study, only 'routine' metabolic rates of prawns are available. However, it is suggested that the values of oxygen consumption presented in the starvation experiments, especially those obtained for P. semisulcatus, are not markedly affected by spontaneous activity and are close to the standard metabolic rate. This

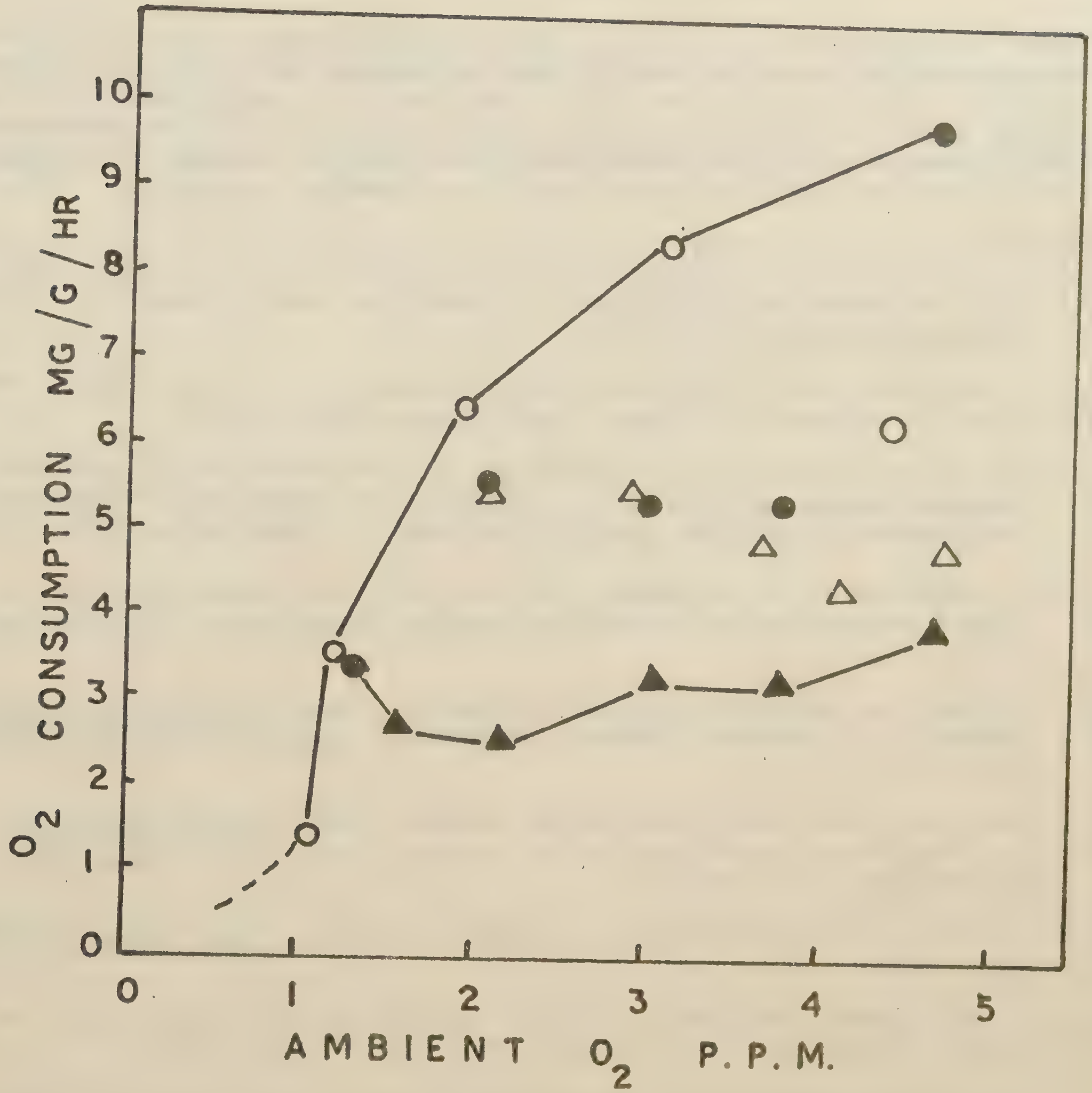

Fig. 5 Oxygen consumption in relation to ambient oxygen in Penaeus indicus in sea water at 30°C. Different symbols designate individual prawns tested: open circle, 14.5g; closed circles, 13.4g; open triangles, 10.6g; closed triangles, 11.4g. The line connecting the highest level of routine metabolism is closest to active metabolic rates; the line connecting the lowest points denotes levels closest to standard metabolism.

contention is supported by the fact that when metabolic rates (0.152 ± 0.016 mg/g/h : mean ± one S.E.) of non-buried prawns (P. semisulcatus) were compared with the values (0.150 ± 0.020 mg/g/h) of buried (resting) prawns (cf. Dall, 1958; Egusa, 1961), the difference between the two was found to be not significant (t = 0.073; d.f. = 13). It is also of interest to note that the decline in the oxygen consumption of both species of prawn due to starvation appears to be sharp, as in the case of the standard oxygen consumption of fishes studied by Beamish, and not gradual as in the case of routine rates exhibited by fishes and other poikilotherms. It is thus likely that the decrease in oxygen consumption in starved prawns, especially in the case of P. semisulcatus, is primarily due to starvation and not due to a mere reduction in spontaneous activity.

Results obtained suggest that when the amoung of available dissolved oxygen is the same, prawns starved for about two days or over can survive for a longer period than those not starved (about 1.7 times as long in the case of P. indicus and 2.3 times in P. semisulcatus under the conditions of the present experiments). The information obtained can be applied profitably when one is faced with the problem of transporting live prawns in water in which the oxygen supply is limited.

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E/56

FACTORS CONTROLLING THE TIME OF EMERGENCE OF PINK SHRIMP, *Penaeus duorarum* [1]

by

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Abstract

The activity of pink shrimp shows a clear phase relationship with the day-night cycle. This study examines the mechanisms whereby the synchrony of emergence from the sand at the time of sunset is maintained between all members of the population.

The results indicate that emergence is under the influence of a circadian rhythm in phase with the light-dark cycle. A periodically changing responsiveness to a light-dark transition indicated the importance of the latter as a 'Zeitgeber', maintaining synchrony between the circadian rhythm and the light-dark cycle.

A 24 h feeding rhythm was indicated by experiments in which shrimp, induced to emerge to feed during the day, would again emerge and carry out food searching movements at approximately the same time the following day when no food was present.

The adaptive significance of these rhythms and their effect on the synchrony of emergence is discussed.

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[1] Contribution No. 1072 from the Institute of Marine Sciences, University of Miami, Miami, Florida 33149, U.S.A.

FACTEURS DETERMINANT LA SORTIE DE LA CREVETTE Penaeus duorarum

Résumé

L'activité de Penaeus duorarum se révèle nettement liée au rythme nycthéméral. L'auteur étudie les mécanismes par l'action desquels tous les individus de la population sortent du sable au moment où le soleil se couche.

D'après les résultats, la sortie de l'animal est sous l'influence d'un rythme quasi journalier correspondant à la variation nycthémérale. La modification périodique de la réponse au passage de la lumière à l'obscurité met en relief l'importance de ce dernier phénomène, qui joue le rôle de "Zeitgeber", assurant le synchronisme entre le rythme quasi journalier et le cycle nycthéméral.

Un cycle alimentaire de 24 heures a été mis en évidence par des expériences durant lesquelles les crevettes, qui avaient été incitées à sortir pour se nourrir durant la journée, réapparaissaient à peu près à la même heure le jour suivant et se mettaient en quête de nourriture même en l'absence de celle-ci.

L'auteur examine l'importance que présentent ces rythmes du point de vue de l'adaptation et leur incidence sur le synchronisme de la sortie.

FACTORES QUE REGULAN LA APARICION DEL CAMARON ROSADO Penaeus duorarum

Extracto

La actividad del camarón rosado muestra una clara relación de fase con el ciclo día-noche. En este estudio se examinan los mecanismos por los que se mantiene entre todos los miembros de la población la sincronía de la salida desde la arena en el momento del crepúsculo.

Los resultados indican que tal salida se halla bajo la influencia de un ritmo cuasi-diario en la fase con el ciclo luz-oscuridad. Una respuesta periódicamente cambiante a la transición luz-oscuridad indicó la importancia de la última como "Zeitgeber", manteniendo la sincronía entre el ritmo cuasi-diario y el ciclo luz-oscuridad.

Los experimentos realizados con camarones, a los que se inducía a salir para alimentarse durante el día, indicaron que el ritmo de alimentación era de 24 horas; éstos volvían a salir y se desplazaban en busca de alimentos a la misma hora aproximadamente del día siguiente, cuando carecían de ellos.

Se examina la importancia de la adaptación de estos ritmos y sus consecuencias sobre la sincronía de la salida.

1 INTRODUCTION

Diurnal patterns of activity occur in most species of shrimp. Most species are recorded as active above sand at night and buried by day, and in this category are Metapenaeus bennettae Racek and Dall (as M. mastersii (Haswell)), M. monoceros (Fabricius), Penaeus aztecus Ives, P. japonicus Bate, P. monodon Fabricius and P. semisulcatus de Haan (Idyll, 1950; Dall, 1958; Egusa and Yamamoto, 1961). On the other hand, P. setiferus (Linnaeus) is said to be active by day and is thought to burrow at night (Idyll, 1950). Racek (1959) records that the Australian shrimp P. plebejus Hess and Metapenaeus macleayi (Haswell) are only active just before and just after sunrise. It was found that P. indicus H. Milne Edwards never burrowed by day or night (personal observations).

The nocturnal activity of P. duorarum Burkenroad, has been recorded by Idyll (1950), Iversen and Idyll (1959), Williams (1955, 1958), Viosca (1957), Eldred (1958), Eldred et al. (1961), Fuss (1964), Fuss and Ogren (1966) and Wickham (1966). Most of these records are, however, the results of incidental observations, and little is known of the nature of the control of this periodicity in behavior.

Fishermen have long been aware that overcast weather or murky waters can increase their catches during the day. Conversely, an increase of light intensity at night may cause reburrowing of shrimp which are already above sand (Eldred et al., 1961). Fuss and Ogren (1966) suggested that "the daily activity patterns of pink shrimp seem to be primarily controlled by photoperiod and other modifying environmental factors but there is some evidence of an endogenous component". The presence of the latter was clearly shown by Wickham (1966) who found that a rhythm controlling the times of activity would persist for longer than a week, under apparently uniform external conditions.

This study concentrates on one aspect of the diurnal activity pattern, the initial emergence from the sand at dusk. This activity is markedly synchronised in all members of the population. An attempt is made here to determine the factors eliciting emergence and maintaining its synchrony in all individuals.

2 METHODS

The shrimp used in the experiments were all juveniles (subadults) and were housed in twelve 60 l aquarium tanks with a sand substrate 6 to 8 cm deep. The water, maintained at a depth of approximately 20 cm was in constant circulation and aerated through subsand filters.

The tanks were enclosed in a light-proof enclosure within a laboratory. The shrimp were exposed either to natural day-night cycles, by uncovering the window against which the tanks were placed, or artificial cycles of light and dark, by the use of a time switch connected to a 150 W flood lamp. The flood light was diffused by deflecting it off the white roof of the enclosure.

The shrimp were netted from a canal in the Everglades of southern Florida. In each tank 6 to 10 shrimp (3 to 12 cm total length) were housed and fed on small pieces of fish (mullet). Virtually no mortality occurred and, unless the water became polluted or the circulation and aeration mechanisms failed, the shrimp appeared healthy.

3 RESULTS

3.1 Diurnal pattern of burrowing behavior

The activity of this species indicates a clear phase relationship with the day-night cycle. Fig. 1a shows the typical pattern of burrowing behavior of 50 shrimp recorded on three consecutive days when exposed to a natural day-night cycle. The shrimp are active above the substrate at night but are inactive and buried during the day. The close association between sunset and the onset of activity (in this case emergence) confirms the records of Fuss and Ogren (1966) and Wickham (1966). These workers also reported a two peaked pattern of occurrence above sand at night, similar to that shown in the figure.

The persistence and circadian periodicity of this pattern under conditions of low light intensity (Wickham, 1966) is confirmed by the results expressed in Fig. 1b. The pattern is shown here for only three consecutive days, but, as shown by Wickham (1966), the evening "peak" of emergence was still clearly noticeable after one week and the free running period throughout this time was clearly longer than 24 h.

These results suggest that a circadian rhythm in phase with the light-dark cycle is responsible for the observed pattern of occurrence above sand (Fig. 1a).

When the light-dark transition was advanced or retarded by 1 h, the time of emergence closely followed the transition, suggesting that the latter is the factor which maintains synchrony between the circadian rhythm and the light-dark cycle (Zeitgeber). If this is the case, a "periodically changing sensitivity of the organism to the stimuli of the Zeitgeber" (Aschoff, 1965) should be apparent. To determine this, emergence was recorded after imposing light-dark transitions at 09:00, 12:00, 15:00 and 18:00 h. Prior to each experiment, all shrimp (n = 75-100) were maintained under a 12 h - 12 h light-dark cycle for at least 10 days. This cycle coincided closely with the natural cycle. The time of the light-dark transition was 18:00 h and was abruptly imposed.

Patterns of emergence, compared here and in later experiments, were markedly consistent for different groups of shrimp maintained under identical light-dark cycles and temperatures, and similarly fed. These patterns can therefore be used as reliable indices of the influence of all stimuli effecting emergence under a particular set of conditions.

Emergence, as a response to a light-dark transition imposed at 18:00 h was relatively rapid (Fig. 2). At a temperature of 25°C, 90 percent or more emerged within the first 30 min of the light-dark transition. Following emergence, the shrimp carried out swimming and food searching movements; they seldom reburrowed until several hours later, at the time of the quiescent period between the peaks of activity.

If the light-dark transition was imposed at a time other than at 18:00 (i.e. at 09:00, 12:00 or 15:00 h) emergence occurred more slowly. Seldom more than 50 percent emerged within 90 min. Those that did were seldom active and a large proportion would reburrow within an hour.

This is clear evidence for a changing responsiveness to the light-dark transitions and implies that the light-dark transition is the Zeitgeber, or an important component of it, which maintains the synchrony between the internal oscillation of the rhythm and the external light-dark cycle.

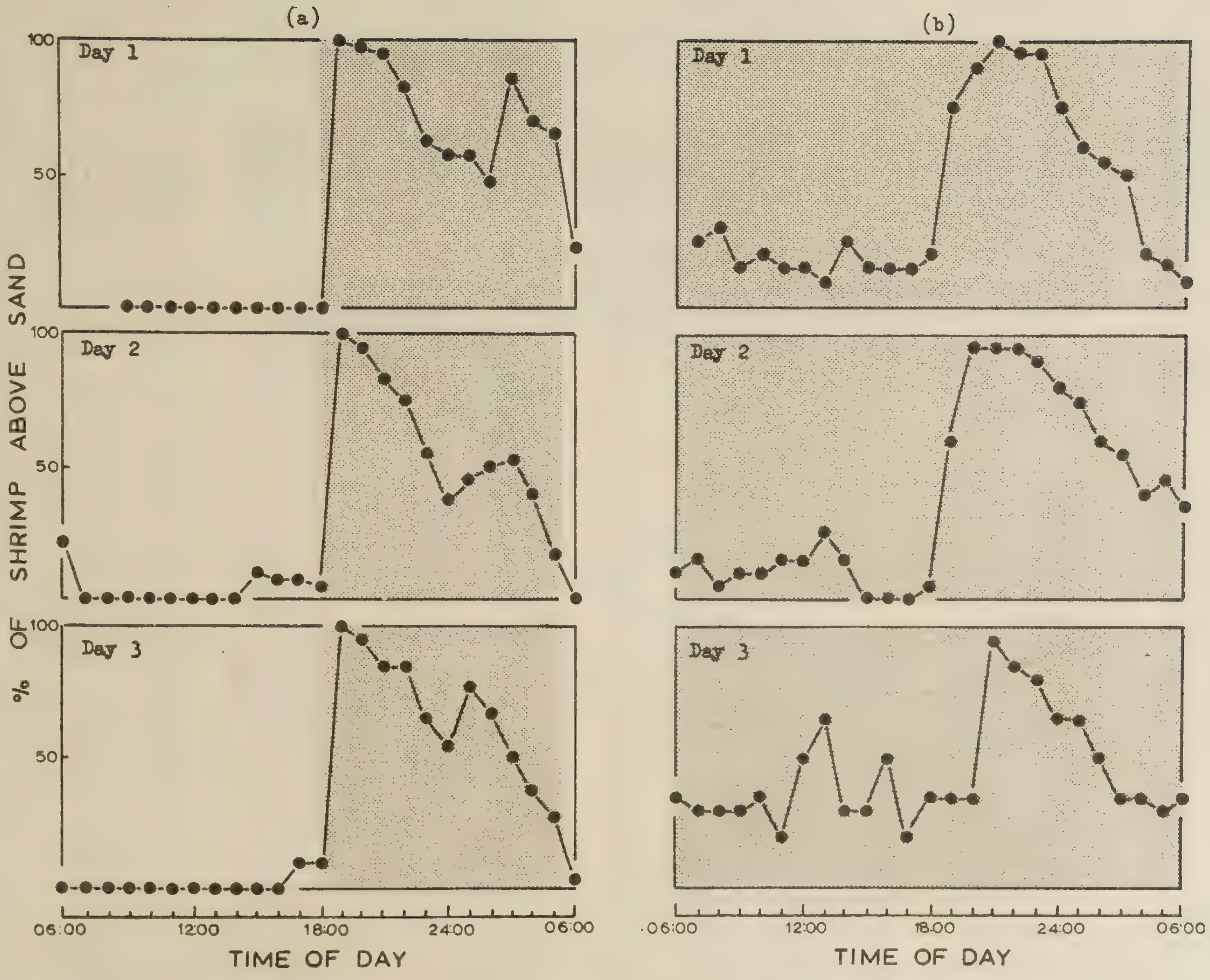

Fig. 1 The burrowing of shrimp during three consecutive days when exposed to (a) a natural day-night cycle and (b) to constant low intensity illumination. Ten shrimp were housed in each of five tanks: counts of the number of shrimp above sand were taken at hourly intervals.

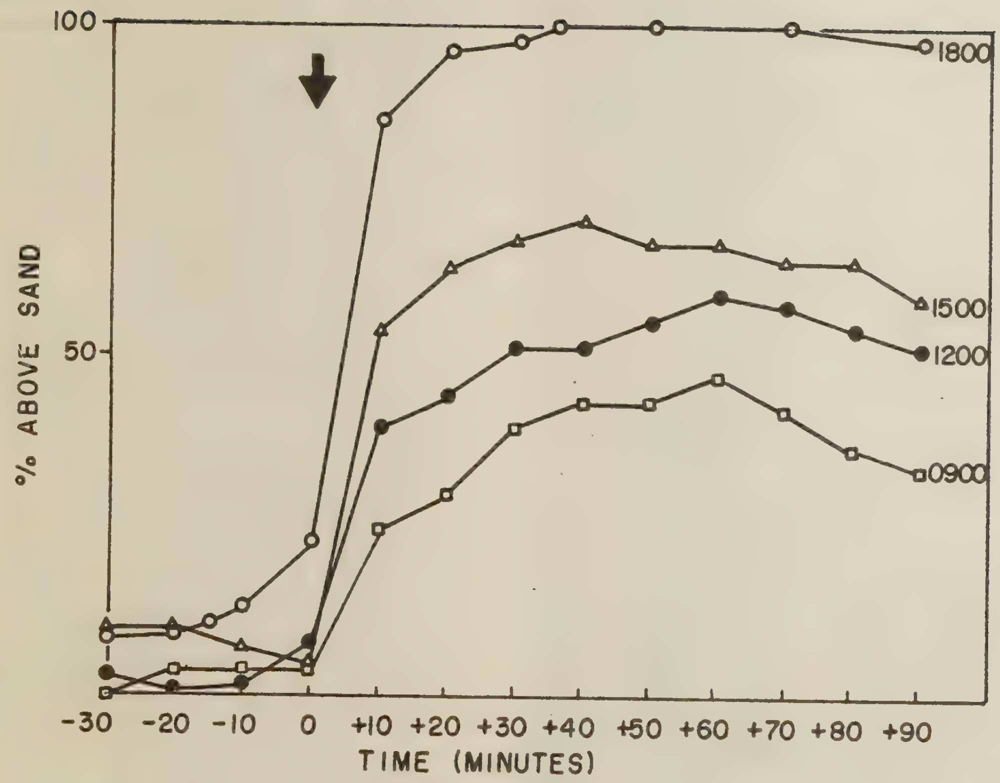

Fig. 2 The pattern of emergence of shrimp when exposed to light-dark transitions imposed at 09:00, 12:00, 15:00 and 18:00 h. The shrimp had been entrained to a LD 12:12 cycle in which the light-dark transition occurred at 18:00 h.

3.2 Phase-shifting of the light-dark cycle

To elucidate further the nature of the factors responsible for the phase synchronization of the rhythm with the environment, experiments involving shifts of the phase of the light-dark cycle were conducted.

The phase of the rhythm should be readily resynchronized to a shifted Zeitgeber, and the response of the rhythm to such a shift has been commonly employed to indicate the phase dependence of the rhythm on a particular environmental factor. (For a review of the literature on entrainment see Aschoff, 1963). Aschoff (1960) stated that "if the Zeitgeber is fully effective the organism should follow the shift within a few periods and should regain the original phase relation to the Zeitgeber".

In the following experiments, the phase of the light-dark cycle was altered through an angle of 120°, so that the light-dark transition occurred at 10:00 h instead of 18:00 h. A 12 h - 12 h light-dark cycle was again imposed after the phase-shift, and the pattern of emergence at the time of the light-dark transition was recorded for several days under the altered regime. The behavior of two groups of 40 shrimp, all of similar size, was compared. Group A were fed each day after the records of emergence were completed (at approximately 11:30 h). Group B were starved after the cyle had been shifted. Daily records were continued until emergence was once more maximal (as at 18:00 h prior to the phase-shift) and until subsequent activity occurred without reburrowing. At this time, the circadian rhythm was considered to have returned to its prior phase relationship with the shifted Zeitgeber.

Emergence of group A after exposure to only one cycle of the altered light regime was almost maximal. The equivalent pattern of emergence was only achieved by group B, following a series of transient stages, after four days exposure to the altered cycle. It appeared, however, that group A did not achieve complete resynchronization with the shifted light-dark cycle after only one day because, despite the almost maximal emergence, there still remained the tendency of some shrimp to reburrow after emergence. (This is presupposing that emergence and subsequent activity are both responses to the same oscillating system). By the third day, however, the pattern of emergence and subsequent activity of group A could not be distinguished from that of shrimp long exposed to a particular light-dark cycle. Group B, by comparison, required six days to reach an equivalent pattern.

3.3 The effects of feeding and food deprivation on emergence

Experiments were conducted to determine whether the slower resynchronization of the rhythm with the light-dark cycle which occurred in group B (unfed) compared with group A (fed) was due to starvation causing a consequent depression of activity.

The pattern of emergence of 40 shrimp which had not been fed for four days was compared with that of an equivalent group, maintained under identical conditions but fed each day after the onset of the dark period. For this experiment, emergence was again recorded when a light-dark transition was imposed at 10:00 h on shrimp that had been entrained to emerge at 18:00 h.

In two out of three repetitions, the rate and degree of emergence of the unfed shrimp was greater than that of the fed shrimp. On the third occasion, there was no noticeable difference between the two groups. These results suggest that the difference in the time taken to resynchronize the rhythms of the fed and the unfed shrimp, following phase shifting of the external light cycle, was not a consequence of starvation.

3.4 Evidence for a feeding rhythm

To separate emergence which could be the result of a feeding rhythm from normal nocturnal emergence and activity, the shrimp were fed at midday, and their emergence recorded the following day. (Under normal circumstances the shrimp do not emerge during the day, however, when not satiated, they can be induced to emerge if food is placed in the tanks).

Two groups (A and B), each comprising 25 shrimp, were used in this experiment. They were both held under identical conditions (LD $13\frac{1}{2}:10\frac{1}{2}$) but were fed at different times.

On day 1, group A was fed at 12:30 h; group B was fed at 19:45 h.

On day 2, records of emergence were taken. Group A emerged in large numbers at approximately midday (24 h after they had been fed). Very few of group B emerged during the same period.

Group B was then fed at 13:40 h (and emerged to feed).

Group A was not fed until 19:45 h that evening.

On day 3, the results were similar to those of day 2 except that in this case, group B emerged at approximately 13:40 h while very few of group A emerged at that time.

4 DISCUSSION

The time of activity of this species indicates a clear phase-relationship with the day-night cycle. The most marked manifestation of this association is the close relation existing between the time of emergence from the sand and the time of the light-dark transition of the day-night cycle. Emergence of almost the entire population takes place within a period of 20 to 30 min at about the time of sunset, and, should the time of this light-dark transition be shifted in either direction by an hour, it is always followed by a shift in the mean time of emergence. The findings of this study elucidate the mechanisms whereby this synchrony of emergence between all members of the population is maintained.

Two rhythms are involved: (i) a circadian rhythm in phase with the light-dark cycle and (ii) a 24 h feeding rhythm. Experiments were designed to distinguish the influence of each and they are discussed separately below.

(i) Circadian rhythm of emergence from the sand

The shrimp showed a periodically changing responsiveness to light-dark transitions (Fig. 2). Although they would always, to a greater or lesser extent, emerge when a light-dark transition was imposed, their rate and degree of emergence was far greater at the time of the light-dark transition of a light-regime to which they had become entrained. The phase dependence of the rhythm on the light-dark cycle was shown by experiments in which the latter was shifted through 120°. Six days of entrainment to the altered cycle was required to resynchronize the rhythm in shrimp which were not fed following the shift of cycle, indicating that the basis of this rhythm is independent of the 24 h feeding rhythm. This is in accordance with Aschoff's (1963) findings which showed that in general, many organisms need three to six days for a 6 h phase shift, i.e. 1 to 2 h shift per day.

An indication of the influence of the rhythm is further shown by the fact that, after phase synchrony had been achieved in the above mentioned experiment, emergence of about 40 percent of the population occurred at the time of the light-dark transition even when no transition was imposed.

(ii) 24 h feeding rhythm

The time taken to resynchronize the phase of the rhythm with a phase shift in the light-dark cycle was considerably shorter in shrimp fed after the light-dark transition than in those unfed during the period of reentrainment. A feeding rhythm with an approximate 24 h periodicity, was probably responsible for this difference. This rhythm was indicated by experiments in which shrimp, induced to emerge to feed during the day, would again emerge and carry out food searching movements at approximately the same time the following day when no food was present.

A characteristic of this rhythm is the readiness with which it can be re-set, regardless of the extent of the shift involved. The strength of the response is suggested by the fact that emergence took place despite the inhibitive factor of the high light intensity.

The results are evidence for the existence of an endogenous "time sense" similar to that first described in bees by Forel (1910) and reviewed more recently by Renner (1960).

4.1 The possible adaptive significance of synchrony of emergence

The nocturnal activity of shrimp and the close association of its onset with the light-dark transition has a number of possible advantages. The observations of Fuss (1966) have indicated that shrimp active above the substrate during the day readily fall prey to many species of fish. A great measure of protection from predators is acquired, therefore, by the limitation of the time of activity to the time of darkness.

In inshore areas where tidal influence is strong, shrimp are passively displaced by either ebb or flood tide. By being passively transported solely by the flood tide, postlarvae are carried into the nursery areas while the juveniles, by being transported only on the ebb tide, are carried out of them (Hughes, 1969). Due to this mechanism of transportation, shrimp, emerging at very different times in the evening, would often become separated by great distances if no synchrony of emergence existed between all individuals.

In addition, it is probable that all activities occurring at night are related temporally to the time of onset of activity at dusk. Consequently, this initial synchrony will considerably influence the synchrony of subsequent activities.

The evidence for this derives from experiments carried out in the current-chamber described by Hughes (1969). Changes in direction or intensity of swimming within the current occurred at similar times in all individuals (manuscript in preparation). It is therefore possible that aggregations of shrimp are largely maintained by the rhythmic control over most activities, and their consequent synchrony in all individuals. Maintenance of these aggregations may have survival value with regard to predators and would be clearly advantageous at times of mating and spawning, producing groups at a similar developmental stage at suitable spawning sites.

The apparent advantage of the circadian rhythm controlling emergence and possibly subsequent activity is clear, but that played by the 24 h feeding rhythm is less clear. In regions where tidal influence is not strong, displacements associated with the ebb and flood tide may not occur. Under these conditions, their first activity following emergence will probably be feeding. Thus, the two rhythms will be virtually in phase and will reinforce each other in such a way that emergence of all individuals should become more closely synshronised. However, when regular displacements by tide occur, the feeding rhythm may interact with responses to ebb and flood tides, in such a way that feeding occurs only when it will not conflict with the time during which displacement by the tide occurs.

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DISCARDING PRACTICES IN THE GULF OF MEXICO SHRIMP FISHERY [1]

by

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Abstract

Studies were conducted to determine the causes and extent of shrimp discarding on the Tortugas pink shrimp and Texas brown shrimp grounds. Information was obtained from direct observations on commercial fishing vessels and from interviews with shrimp fishermen. Discarding declined markedly on the Tortugas grounds from 1963 to 1966, apparently due to increases in the value of small shrimp. Other factors, including the reluctance of processors to purchase small shrimp and a minimum size restriction, appear to influence discarding practices on offshore Texas grounds.

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LE REJET A LA MER DANS LES PECHERIES DE CREVETTES DU GOLFE DU MEXIQUE

Résumé

La communication rend compte d'une étude tendant à déterminer les motifs et l'importance des rejets de crevettes à la mer dans les pêcheries du golfe du Mexique, les espèces visées étant la "crevette rose" (Penaeus duorarum Burkenroad), récoltée dans la zone des Tortugas, et la "crevette brune" (Penaeus aztecus Ives), pêchée au large du Texas. Les renseignements ont été obtenus par observations effectuées à bord de navires de pêche commerciale et interrogatoires directs de pêcheurs. De 1963 à 1966, la pratique du rejet à la mer a nettement diminué dans la pêcherie des Tortugas, apparemment en raison du relèvement des cours des petites crevettes. Pour ce qui est des fonds de pêche au large du Texas, le rejet à la mer paraît être influencé par d'autres facteurs, notamment le peu d'intérêt manifesté pour les petites crevettes par les transformateurs, et l'imposition d'une taille minimale.

CAPTURA DESECHADA EN LA PESQUERIA DE CAMARONES DEL GOLFO DE MEXICO

Extracto

Se realizaron estudios para determinar las causas y la proporción del camarón devuelto al mar en los caladeros de camarón rosado de las islas Tortugas y en los de camarón marrón de Texas. Se obtuvo información de las observaciones directas realizadas en las embarcaciones de pesca comercial y de las entrevistas sostenidas con los pescadores de camarones. La cantidad de camarón desechado disminuyó bastante en los caladeros de las Tortugas desde 1963 a 1966 debido, al parecer, al aumento de valor del camarón pequeño. En el desecho de camarón en los caladeros de las costas de Texas parecen influir otros factores, como la resistencia de los elaboradores a comprar el camarón pequeño y las restricciones sobre la talla mínima.

1 INTRODUCTION

An important, but seldom measured, element of many commercial fisheries is the portion of the catch that is discarded at sea. Unless the species of interest survives after being caught and thrown back, the resource is diminished with no direct gain to man. Discarding can be of particular significance if the gear used in a fishery commonly takes individuals that are too small to be marketed.

The practice of culling and discarding small shrimp apparently is widespread in the shrimp fishery of the Gulf of Mexico, but the subject has received little attention in the literature. Reports from fishermen indicate that the number of shrimp discarded from different catches is extremely variable, ranging from none to two-thirds of those landed on deck. Iversen and Idyll (1959) reported that on the Tortugas grounds near Key West, Florida, 36 percent of the number of shrimp caught by a chartered research vessel was culled by the fisherman-captain during simulated commercial operations. They noted also that a greater proportion of the catch might be discarded if a fisherman was seeking large shrimp where small shrimp were abundant. Iversen, Jones and Idyll (1960) concluded that small shrimp are culled only when few are caught, and it is not worth the effort or expense to ice them separately from the rest of the catch.

Our endeavours to obtain further information about the extent and causes of discarding began in the summer of 1962. Fishermen reported that large quantities of small brown shrimp were discarded in areas off the Texas coast in July and August of that year. In mid-August and on several later occasions, a biologist accompanied commercial fishermen to observe culling practices at sea. The time required to carry on such observations made it apparent that another approach was needed if we were to obtain more than general information about the subject. Beginning in September 1963, we started an interview survey of fishermen who landed shrimp at certain ports to determine the approximate weight of small shrimp that they discarded at sea. This report presents the results of these investigations and discusses some of the causes of discarding.

2 CONDITIONS THAT AFFECT DISCARDING

A fisherman's decision to keep or discard the small shrimp in his catch is probably influenced by several considerations, most of which are well known to persons familiar with the shrimp fishery.

2.1 Availability of small shrimp

The time of year when small shrimp are available to the fishery depends on the species and on laws governing harvests. The commercial fishery in the Gulf of Mexico is supported by three species: the brown, Penaeus aztecus Ives; the white, P. setiferus (Linn.); and the pink shrimp, P. duorarum Burkenroad. Each spawns in offshore Gulf waters and the young enter coastal bays as postlarvae. Generally, brown and pink shrimp return to offshore waters sooner and at a smaller size than white shrimp. Landing data are portrayed in Fig. 1 to show the seasonal availability of small shrimp of the three species. (The term small shrimp, as used here, refers to those numbering 68 or more to the lb (150 or more /kg) with heads removed).

The fishery operates both in estuaries and offshore, if local conditions and statutes permit. Because shrimp move seaward during the juvenile or subadult stages, the size composition of catches varies with depth and distance from shore; the proportion of small shrimp landed is greatest when fishing is concentrated near the coast.

2.2 Value of small shrimp

The value of small shrimp must play an important part in determining a fisherman's attitude toward discarding, but data are not available in the literature to verify this point. Considering all U.S. landings from the Gulf of Mexico, no significant relation is apparent between average ex-vessel prices and annual landings of small shrimp (Table

I). At a particular port, however, value would be expected to decrease when supply exceeded demand.

TABLE I

Average ex-vessel price and total weight of small shrimp (68 or more per lb) caught in the Gulf of Mexico and landed at U.S. ports, 1956-66

Year	Average price per lb	Weight of small shrimp landed	Small shrimp in total landings
	(U.S. cents)	(Millions of lb)	(%)
1956	28.6	17.8	16.4
1957	32.4	11.4	11.5
1958	35.0	10.9	10.7
1959	23.6	12.8	11.4
1960	25.8	13.7	11.4
1961	30.3	9.4	12.1
1962	38.5	16.4	18.9
1963	20.0	19.8	15.6
1964	26.7	14.7	13.0
1965	29.4	21.8	17.9
1966	36.9	22.8	20.3

Source: Gulf Coast Shrimp Data, Current Fishery Statistics, U.S. Fish and Wildlife Service and Shrimp Landings, Current Fishery Statistics, U.S. Fish and Wildlife Service

Shrimp prices have fluctuated considerably in recent years, probably in response to changes in landings, holdings, imports, and the level of the nation's economy. A comparison of prices paid for large and small pink shrimp in 1958-66 (Fig. 2) indicates that the value of small shrimp is determined largely by the same factors that influence the prices of larger shrimp. Differences between the curves for the two sizes may result from the fact that two markets are involved; most small shrimp are canned, whereas large ones usually are frozen. The price paid for small shrimp in 1958-66 varied by a factor of three, ranging from a monthly average of about 15 to 45 cents per lb (33 to 99 cents /kg).

2.3 Methods of grading

The value of shrimp to the fisherman depends on the size composition of the catch and on the method used to determine size. Landings are purchased according to the num-

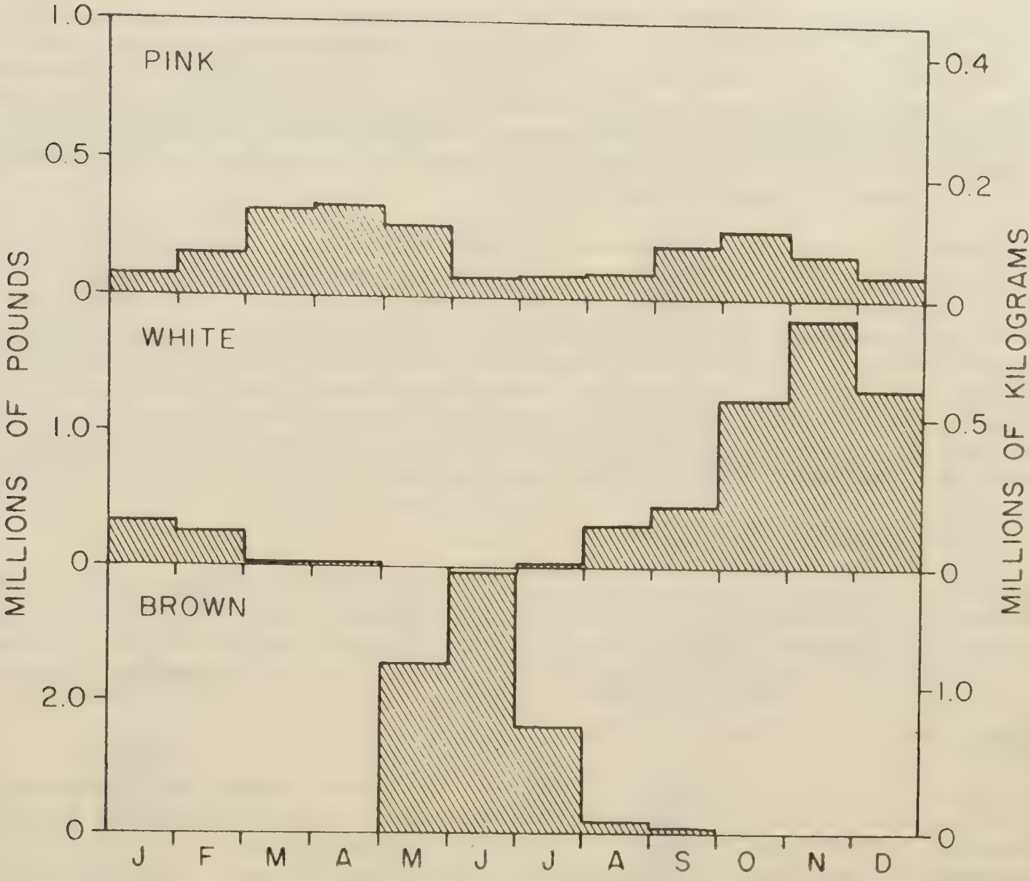

Fig. 1 Average monthly landings (1961-65) of small shrimp (68 or more per lb (150 or more/kg)) from United States waters in the Gulf of Mexico. Source: Gulf Coast Shrimp Data, Current Fishery Statistics, U.S. Fish and Wildlife Service.

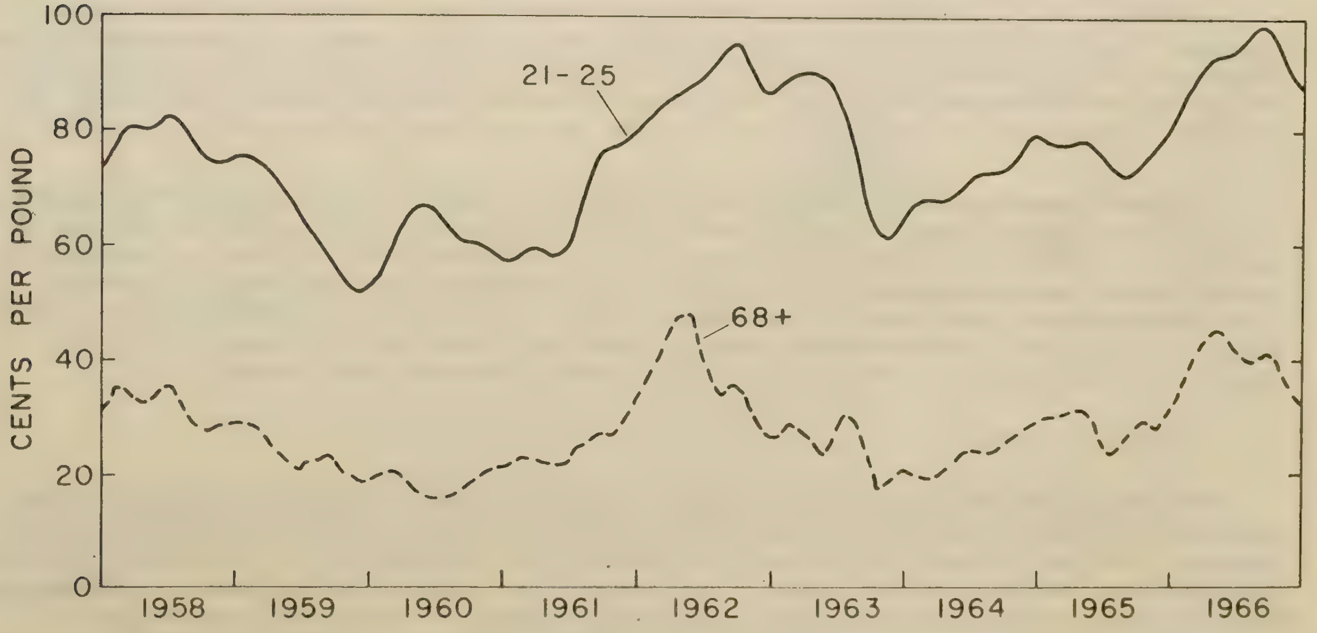

Fig. 2 Average ex-vessel price paid for small (68 or more per lb) and large (21 to 25 per lb (46 to 55/kg)) pink shrimp at ports on the west coast of Florida, 1958-66. (Original data smoothed by a moving average of three). Source: Shrimp Landings, Current Fishery Statistics, U.S. Fish and Wildlife Service.

ber of shrimp per lb, i.e. fewer than 15, 15-20, 21-25, ..., and value increases with size. The size composition of a landing is determined by either box or machine grading, depending on the facilities available and the fisherman's preference. In box grading, several 5-lb samples of shrimp are taken as a vessel is unloaded, and the size category assigned to the landings is based on the average number of shrimp in these samples. In machine grading the shrimp in the entire catch are mechanically sorted into a number of size categories.

When catches consist of a mixture of small and large shrimp, fishermen can influence the total value of a landing by selecting the method of grading that produces the greater revenue and, sometimes, by culling small shrimp. If the entire catch is box graded, the presence of small shrimp depresses the average size and the price per lb. To avoid this, a fisherman can separate large and small shrimp before reaching port and have each portion box graded. When the value of small shrimp is low, however, he may prefer to keep only large ones and discard the others. The fisherman is not penalized by the presence of small shrimp if he elects to have a landing graded by machine, but the total value of the landing may be less than if it were box graded.

2.4 Minimum size regulations

Each of the five Gulf states currently restricts the minimum size of shrimp that may be landed. Regulations differ considerably among states and no size limits apply during specified seasons in some areas. It is permissible for about 5 percent of the shrimp in a landing to be of sublegal size in situations governed by regulations.

3 OBSERVATIONS OF DISCARDING AT SEA

Biologists from the Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas, made several trips aboard commercial shrimp vessels to measure the size of shrimp culled from catches. The usual procedure was for the biologist to set aside a portion of the catch with a shovel soon after the nets were emptied on deck. He then asked a member of the crew to select shrimp that would normally be kept from this part of the catch. Length measurements were taken of shrimp selected as well as those that would have been discarded by the fisherman.

Although trips were scheduled when small shrimp were available on the fishing grounds, discarding did not occur during all voyages. No shrimp were discarded at sea during two trips because the shrimp were not handled individually. When catches are large and contain relatively few fish, some fishermen save the entire catch and, if culling is required, it is done when the landing is graded at the dock.

Length-frequency distributions of shrimp culled or kept during trips to the Tortugas pink shrimp grounds (Florida) and to the Texas brown shrimp grounds are shown in Fig. 3. These data provide an indication of the variation in sizes of shrimp and proportion of catches discarded. Estimates of the percentage of the total shrimp catch discarded during these trips ranged from 0 to 45 percent in numbers and 0 to 29 percent in weight. No difference was apparent in discarding practices in the two areas, but our data were not sufficient to permit definite conclusions.

4 INTERVIEW SURVEYS

We also collected information about discarding practices by interviewing vessel captains as they landed shrimp from the Tortugas and Texas grounds. Interviews were obtained from September 1963 through September 1966 at Marathon and Key West, Florida, and from June through August 1964-66 at Freeport and Aransas Pass, Texas. Information received through the cooperation of fishermen included estimates of the weight of shrimp discarded during a trip and an account of where the discarding occurred.

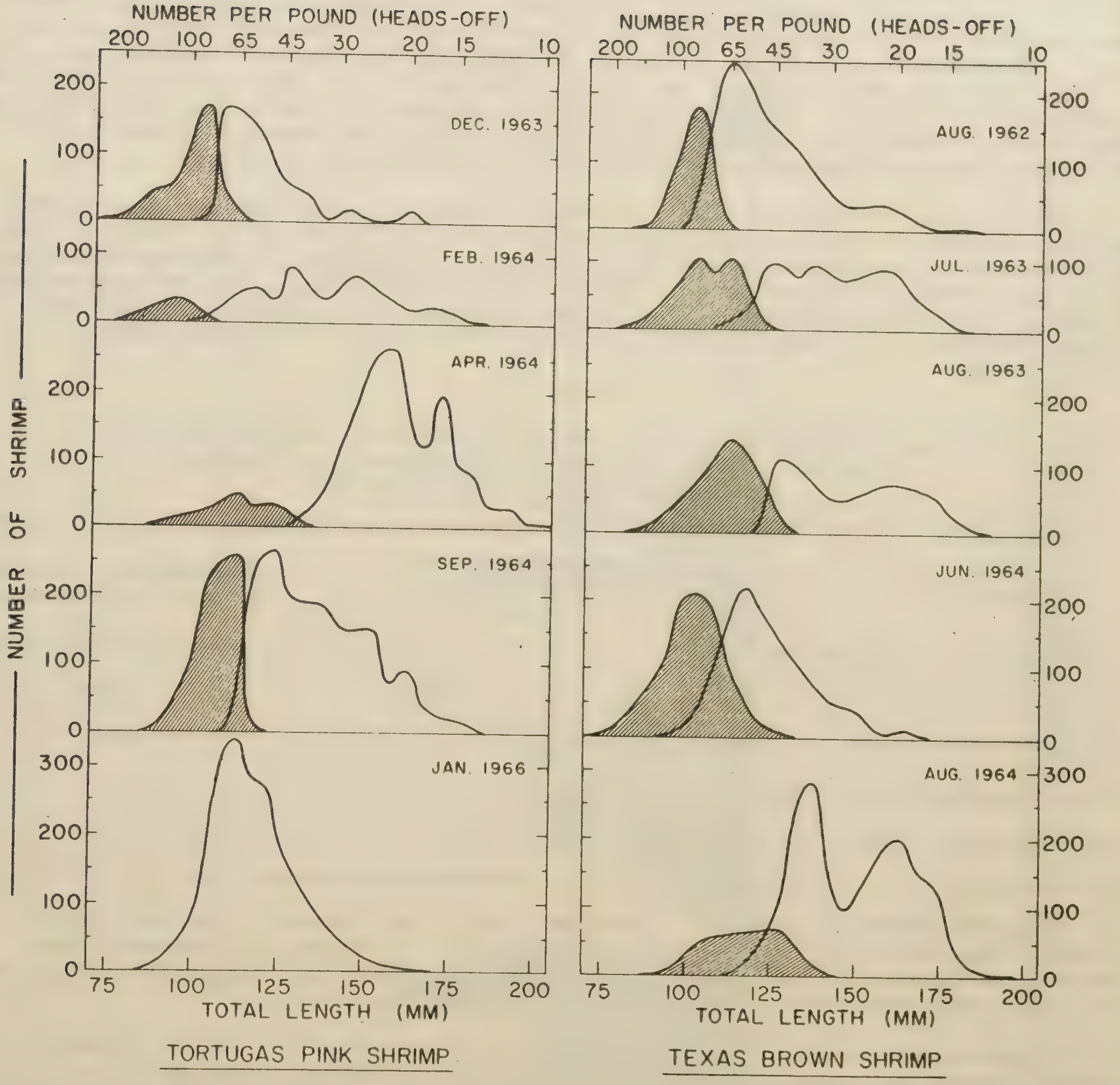

Fig. 3 Length-frequency distributions of shrimp that were culled and discarded (shaded areas) or kept (unshaded) during fishing trips to Florida and Texas fishing grounds.

4.1 Tortugas pink shrimp (Florida)

Interviews with fishermen at Key West and Marathon covered about 75 percent of the landings made at these ports and about half of the total landings from the Tortugas grounds. We have grouped the large volume of data that resulted into annual periods to facilitate presentation. Also, we assumed that the size of discarded shrimp was equivalent to that of shrimp sold in the size category of 68 or more per lb (150 or more /kg). This assumption made it possible to estimate the catch of small shrimp during a time interval and relate discarding practices to the abundance of small shrimp. We believe that the information provided by the fisherman was not biased.

An estimate of the total weight of shrimp discarded can be made from our information and that provided in "Gulf Coast Shrimp Data" (published by the Fish and Wildlife Service in the series entitled Current Fishery Statistics), a monthly tabulation of shrimp landings at United States ports in the Gulf of Mexico. The reported weight of shrimp landed and estimates of the weight discarded on the Tortugas grounds are listed in Table II for annual periods extending from October through September.

TABLE II

Estimated weight of headless shrimp discarded at sea, as indicated by interview data, and weight landed from the Tortugas grounds, October 1963-September 1966

Time period	Total weight landed	Estimated weight and percentage discarded		Percentage of landings covered by interviews
	(lb)	(lb)	(%)	(%)
Oct. 1963-Sept. 1964	11,187,926	789,800	6	40.0
Oct. 1964-Sept. 1965	10,051,716	140,700	1	53.3
Oct. 1965-Sept. 1966	13,153,024	28,200	<1	53.5

A marked change in discarding practices during the 3 years of our survey provided an opportunity to evaluate causative factors. According to fishermen interviewed, one-quarter to one-half of the small shrimp caught were discarded in late 1963, but, none were discarded during July-September 1966 (Fig. 4).

Because the size of shrimp increases from the shoreward edge of the fishing grounds toward deep water (Iversen, Jones and Idyll, 1960), we might expect the percentage of shrimp discarded to be greater in shallow than in deep water. The data showed, however, that the percentages did not vary directly with depth (Table III). Fishermen working in shallow water apparently were seeking small shrimp, whereas those fishing at greater depths were fishing for large shrimp and placed less value on small ones (Table IV).

Methods of grading shrimp landings and discarding practices were directly related (Table V). Discarding at sea was less frequent when landings were graded by machine than when the box grading method was used. We cannot distinguish whether shrimp were culled because of the type of grading that was to be used, or, if the method of grading was selected on the basis of the size composition of the landing. Both situations probably occurred. We also do not have information on culling from machine-graded landings during the grading process.

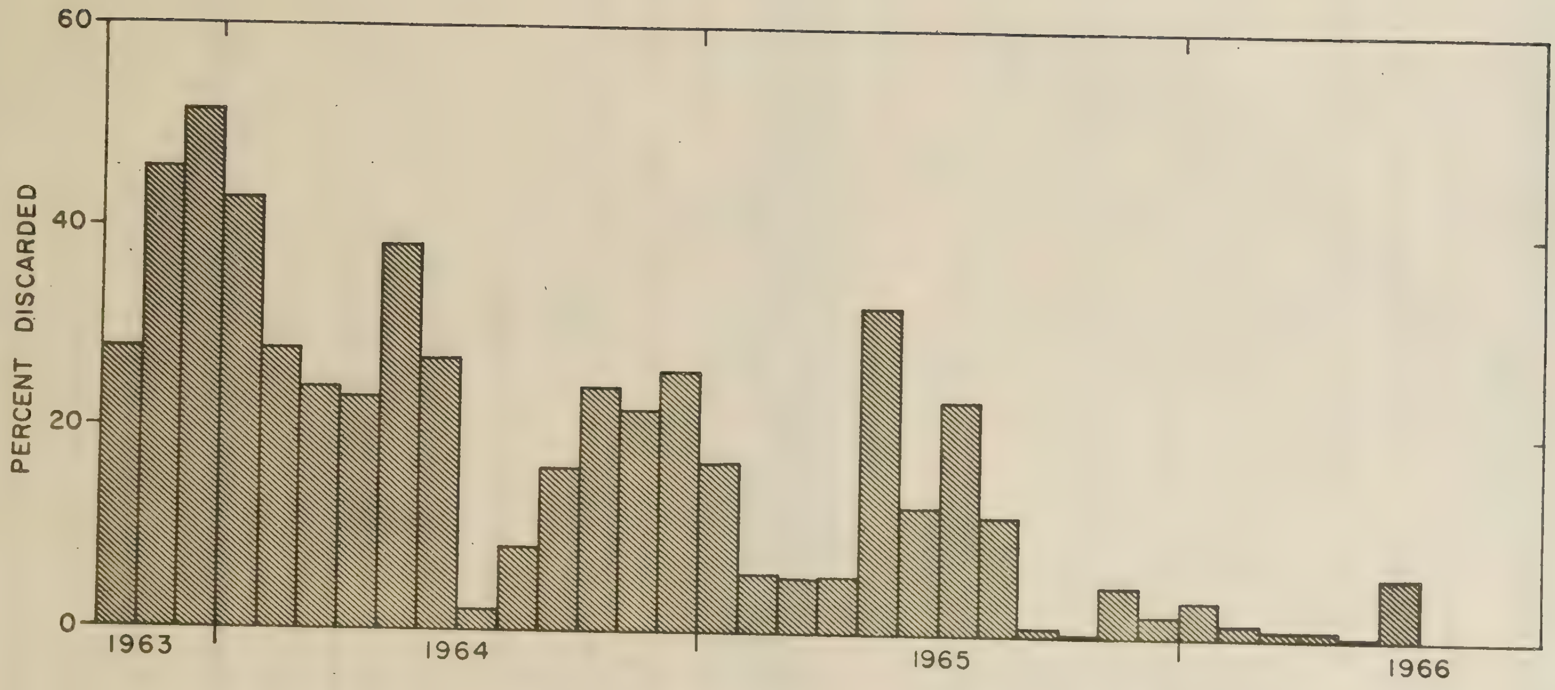

Fig. 4 Percentage (by weight) of small shrimp (68 or more per lb) discarded at sea on the Tortugas grounds, October 1963 to September 1966.

TABLE III

Percentage (by weight) of total shrimp catch discarded on the Tortugas grounds from October 1963 through September 1966, arranged according to depth intervals

Depth (m)	Oct. 1963-Sept. 1964	Oct. 1964-Sept. 1965	Oct. 1965-Sept. 1966
11-20	2.8	0.5	0.1
21-30	7.4	1.5	0.3
31-40	4.6	0.9	0.1
Over 40	2.8	0.4	0.0
Weighted mean	6.6	1.4	0.2

TABLE IV

Percentage (by weight) of small shrimp catch (68 or more per lb) discarded on the Tortugas grounds from October 1963 through September 1966, arranged according to depth intervals

Depth (m)	Oct. 1963-Sept. 1964	Oct. 1964-Sept. 1965	Oct. 1965-Sept. 1966
11-20	4.5	0.9	0.3
21-30	25.7	10.8	1.5
31-40	79.4	44.7	11.9
Over 40	71.7	46.5	0.0
Weighted mean	27.8	11.2	1.5

TABLE V

Frequency of discarding in relation to the method of grading shrimp landed from the Tortugas grounds, October 1963 - September 1966

Time period	Proportion of fishing trips during which shrimp were discarded					
	Machine graded			Box graded		
	Number of post-trip interviews	Interviewees who discarded shrimp No.	%	Number of post-trip interviews	Interviewees who discarded shrimp No.	%
Oct. 1963-Sept. 1964	349	42	12.0	2,650	1,124	42.4
Oct. 1964-Sept. 1965	958	28	2.9	2,681	408	15.2
Oct. 1965-Sept. 1966	904	8	0.9	3,306	62	1.9
Total	2,211	78	3.5	8,637	1,594	18.5

The statistical technique of multiple regression provides an objective means for evaluating effects of some factors that influence discarding. Two equations were formed to test data for the 36 months from October 1963 to September 1966, assuming that discards (Y) were a linear function of the independent variates (X_1, X_2, X_3).

$$(1)\quad Y = a + b\,X_1 + c\,X_2 + d\,X_3$$

$$(2)\quad \frac{Y}{Y + X_2} = a + b\left(\frac{X_2}{X_1}\right) + c\,X_3$$

Y = weight of shrimp discarded per month

X_1 = total weight of shrimp landed per month

X_2 = weight of small shrimp (68 or more per lb) landed per month

X_3 = price per lb for small shrimp (68 or more per lb).

The meaning of terms in equation (2) becomes more evident if symbols are replaced by words:

(2) (Proportion of small shrimp discarded) = a + b (proportion of small shrimp in landings) + c (price per lb for small shrimp).

The two equations provided similar answers to the question - Which factor (or factors) influences discarding practices? The only significant relation in either equation was the dependence of discarding on the price paid for small shrimp. Equation (2) was superior to equation (1) and accounted for about 55 percent of the variation in weight of shrimp discarded. Equation (1) explained 42 percent of the variation in weight discarded. Elimination of the first independent variable in equation (2) indicates that price per lb accounted for 42 percent of the total variation. As indicated in Fig. 2, the value of small shrimp increased throughout the study period and this increase apparently influenced fishermen to retain them for sale. The relation between price and the proportion of small shrimp discarded appears in Fig. 5.

4.2 Texas brown shrimp

Information on discarding of shrimp in the Texas brown shrimp fishery is not directly comparable to that from the Tortugas area. Differences exist in the general nature of the fisheries, in laws governing harvests, and in the availability of small shrimp. The shrimp industry on the Texas coast is geared to handle shrimp of medium or large sizes, and some processors are reluctant to purchase small shrimp (O. H. Farley, personal communication). State laws also discourage fishermen from landing large quantities of small shrimp. Fishing grounds between shore and depths near 20 m are closed to commercial fishing when small shrimp are abundant, and a minimum size restriction of 65 headless shrimp per lb is in effect throughout the year. In further contrast to the situation on the Tortugas grounds, small shrimp are plentiful in offshore Texas waters only from about June through August rather than during most of the year (see Fig. 1).

Our data from interviews obtained at Texas ports represent such a small proportion of landings made during the summers of 1964-66 that we consider them inadequate for estimating the total weight of shrimp discarded. They do provide, however, an indication of the percentage of catches culled (Table VI) and the frequency of discarding (Table VII). A seasonal decline in discards is evident from June through August each year, but there is no indication of the major decrease from 1964 to 1966 that we observed in the Tortugas fishery. Since the value of small shrimp was similar in Texas and Florida during the months of interest (Table VIII), it appears that factors other than price control discarding in the Texas fishery. Presumably, these factors include the reluctance of processors to purchase small shrimp and the minimum size restriction.

TABLE VI

Percentage (by weight) of brown shrimp catches discarded on Texas offshore fishing grounds (20-40 m) during June-August, 1964 and 1965[1]

Month	1964	1965
June	7.7	13.7
July	1.8	4.2
August	0.2	0.1

[1] Estimated weight of shrimp discarded was not obtained during interviews made in 1966.

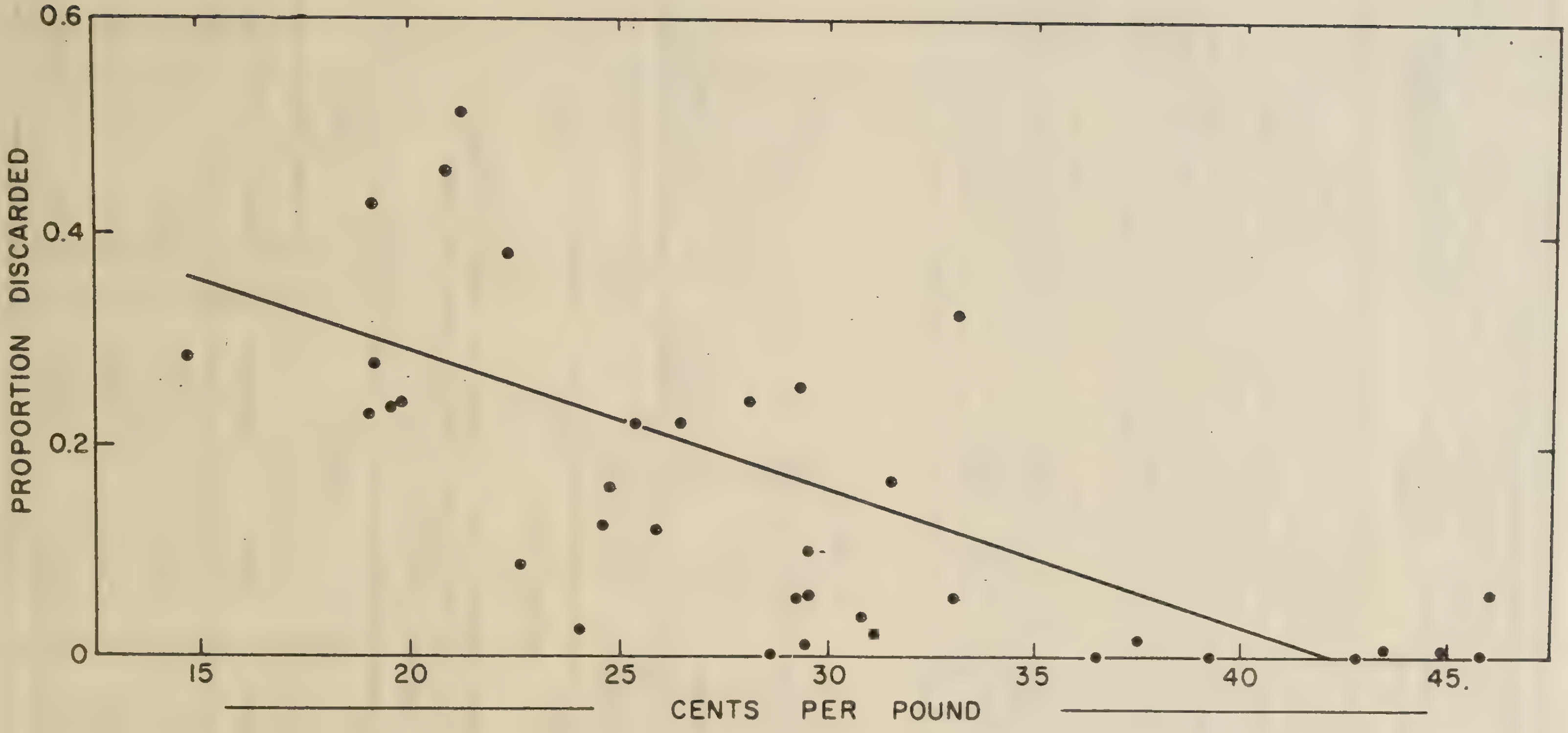

Fig. 5 Proportion (by weight) of the small shrimp catch discarded on the Tortugas grounds as related to their value, October 1963 to September 1966.

TABLE VII

Frequency of discarding during fishing trips to the brown shrimp grounds (20-40 m) off the Texas coast, June-August 1964-66

Year and month	Number of post-trip interviews	Interviewees who discarded shrimp Number	Percentage
1964			
June	246	81	32.9
July	694	115	16.6
August	860	35	4.1
1965			
June	229	104	45.4
July	793	219	27.6
August	676	31	4.6
1966			
June	127	35	27.6
July	323	25	7.7
August	292	16	5.5
Total	4,240	661	15.6

TABLE VIII

Average ex-vessel price (cents) per lb paid for small shrimp (68 or more per lb) at Texas and Florida ports in the summers of 1964-66

Month	1964		1965		1966	
	Texas	Florida	Texas	Florida	Texas	Florida
June	25.0	25.3	17.9	24.5	25.2	39.2
July	28.4	24.0	23.1	19.6	33.0	36.5
August	27.3	22.6	29.9	25.8	42.0	46.0
Average	26.9	24.0	23.6	23.3	33.4	40.6

5 MORTALITY OF DISCARDED SHRIMP

The fate of shrimp discarded at sea is important to an evaluation of culling practices. If the shrimp die, the practice is wasteful, but if they survive, it may have little significance. Shrimp culled from catches remain on the deck of commercial vessels for about 15 to 30 min before they are shoveled overboard. Cursory observations made aboard vessels suggested that most of the shrimp died within this period unless air temperatures were low.

To obtain additional information, we exposed shrimp to air at several temperatures in the laboratory and recorded resulting mortalities. The experiments were conducted in constant temperature rooms after the shrimp had been acclimated for a minimum of 2 days. About equal numbers of brown and pink shrimp measuring from 60 to 130 mm (tip of rostrum to tip of telson) were used in each test. The tests consisted of removing shrimp from sea water tanks and placing them on damp boards for different periods of time. They were then returned to the water and their condition was noted 5 min later. If they appeared normal at that time, we considered that they had survived the experience. Results from several experiments are summarized in Table IX.

These tests suggest that at least half of the shrimp discarded during normal fishing operations die from effects of exposure to air when temperatures reach 20°C. Air temperatures above this level prevail over the Tortugas and Texas fishing grounds (Fig. 6) during times when small pink and brown shrimp are most abundant (Fig. 1). If mortality from other causes such as injuries or predation is also considered, it is probable that very few of the discarded Tortugas pink or Texas brown shrimp survive.

TABLE IX

Mortality of brown and pink shrimp during exposure to air

Air and water temperature	Number of shrimp tested	Period of exposure to air	Mortality
(°C)	(No)	(Min)	(%)
15	27	15	4
15	26	30	12
15	29	45	41
15	35	60	77
23	81	15	78
23	37	30	100
27	25	15	96
30	25	15	100

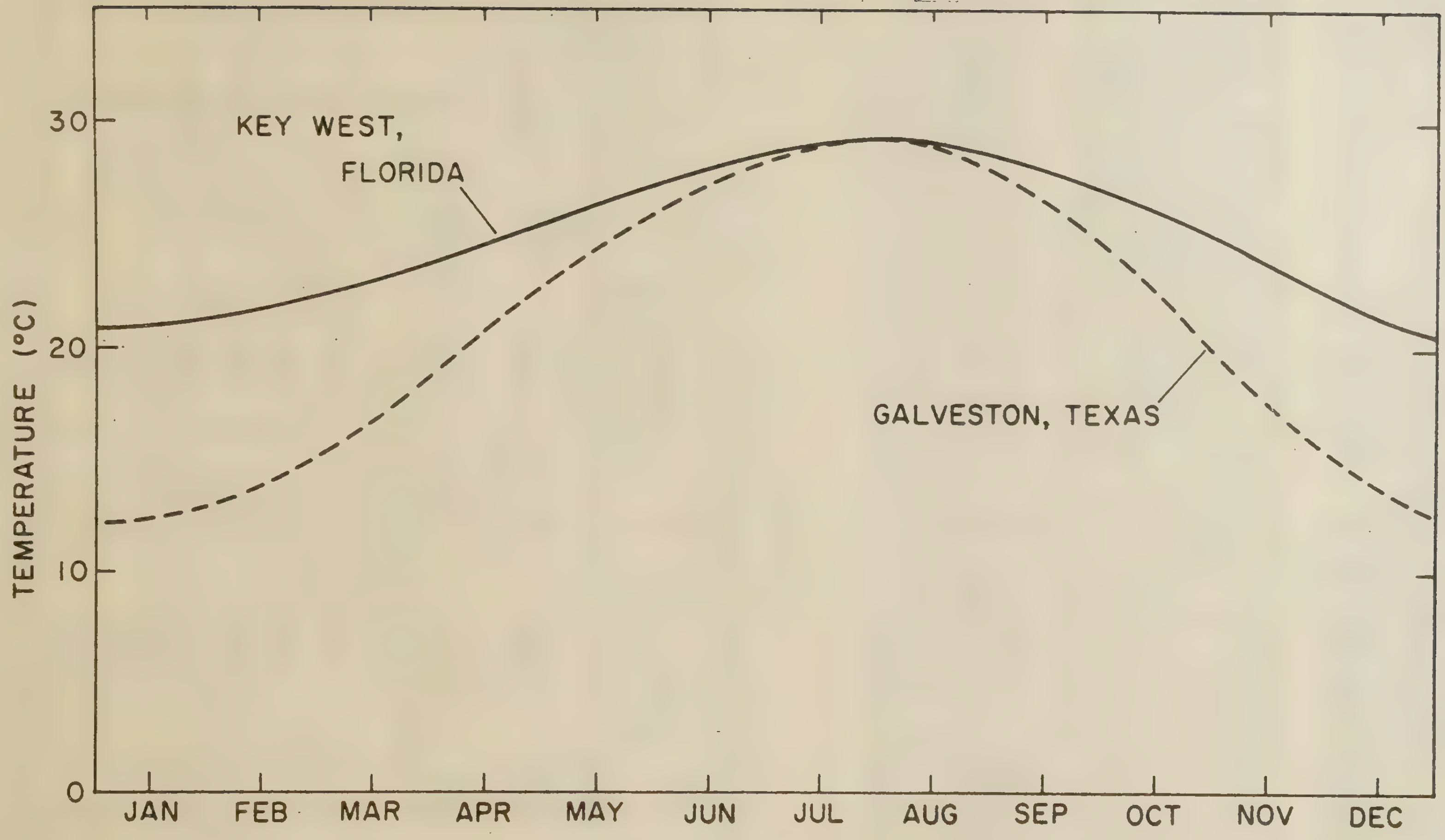

Fig. 6. Average monthly air temperatures at Key West, Florida and Galveston, Texas. Source: Local Climatological Data. Weather Bureau, U.S. Department of Commerce.

6 CONCLUDING REMARKS

For analytical purposes, we have considered the practice of discarding small shrimp separately from most other facets of the shrimp fishery. This approach is convenient for gaining insight into the subject, but does not provide a satisfactory perspective from which to judge the significance of discarding. A realistic appraisal of its importance should be based on broad knowledge of the dynamics of both the shrimp populations and the market. Such information is not presently available.

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* * * * * * * *

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We thank J.H. Hudson who helped conduct the interviews and accompanied fishermen out of Key West, Florida, and J.M. Lyon who performed similar tasks at Aransas Pass, Texas. We are also grateful for the willing cooperation received from shrimp fishermen at ports in Florida and Texas.

WHITE SHRIMP EMIGRATION IN RELATION TO SIZE, SEX, TEMPERATURE AND SALINITY [1]

by

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Abstract

This study was conducted on juvenile and subadult white shrimp, Penaeus setiferus (Linnaeus), emigrating from Galveston Bay, Texas, to the Gulf of Mexico. Surface, midwater, and bottom tows were made with a 3-m otter trawl on ebbing tides from 1 August 1966 to 27 January 1967. Sampling was usually conducted during the day. Five peaks of emigration occurred from 19 October through 25 December, coinciding with water temperatures between 19° and 8° C in the tidal pass. The catch per unit of effort increased significantly from the surface to the bottom of the water column. Sharp drops in water temperature appeared to stimulate shrimp emigration. The mean lengths of shrimp caught were similar between water depths and sexes on a given sampling date, but decreased with progress of the season and decreasing temperature; there was no obvious relation between length and salinity. Of 2,964 white shrimp caught in the tidal pass, 55.1 percent were females, but the sex ratio was not significantly different from 1:1.

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[1] Contribution No. 241 from the Bureau of Commercial Fisheries, Biological Laboratory, Galveston, Texas 77550, U.S.A.

EMIGRATION DE LA CREVETTE Penaeus setiferus (LINNAEUS) EN FONCTION DE LA TAILLE, DU SEXE, DE LA TEMPERATURE ET DE LA SALINITE

Résumé

Les auteurs ont étudié les stades juvéniles et sub-adultes de "crevette blanche" - Penaeus setiferus (Linnaeus) -, qui émigrent de la baie de Galveston (Texas) à destination du golfe du Mexique. Du ler août 1966 au 27 janvier 1967, des traits ont été effectués durant le jusant, en surface, entre deux eaux, et sur le fond au moyen d'un chalut (de 3 mètres) à panneaux. Le prélèvement a généralement eu lieu de jour. On a constaté cinq "pointes" d'émigration, s'échelonnant du 19 octobre au 25 décembre, et coïncidant avec des températures de l'eau du chenal situées entre 19° et 8°C. Les captures par unité d'effort ont accousé une nette progression à mesure que l'on allait de la surface vers le fond. Les chutes brusques de la température de l'eau ont paru stimuler l'émigration des crevettes. Pour une même date d'échantillonage, la taille moyenne des animaux capturés était identique aux différentes profondeurs et pour les deux sexes, mais elle a diminué à mesure qu'avançait la saison et que baissait la température. On n'a pas relevé de rapport évident entre longueur des animaux et taux de salinité. Sur 2 964 crevettes pêchées dans le chenal, le pourcentage des femelles était de 55,1 p. 100, mais la sex-ratio ne s'écartait guère de 1/1.

LA EMIGRACION DEL CAMARON BLANCO EN RELACION CON EL TAMAÑO, EL SEXO, LA TEMPERATURA Y LA SALINIDAD

Extracto

Se estudió el camarón blanco, Penaeus setiferus (Linnaeus), en su forma juvenil y subadulta, al emigrar de la Bahía de Galveston, en Texas, al Golfo de México. Desde el 1 de agosto de 1966 hasta el 27 de enero de 1967, se efectuaron lances en la superficie, entre dos aguas y en el fondo, con una red de arrastre de puertas de 3 m,con marea descendente. Por lo general, el muestreo se hizo durante el día. Desde el 19 de octubre hasta el 25 de noviembre, coincidiendo con temperaturas del agua entre 19° y 8°C hubo cinco emigraciones máximas en el canal de paso de la marea. La captura por unidad de esfuerzo aumentó mucho desde la superficie al fondo. Los bruscos descensos de la temperatura del agua estimulaban, al parecer, la emigración de los camarones. Las tallas medias de los camarones capturados, así como el sexo eran similares a ciertas profundidades en una fecha dada de muestreo, pero disminuían al avanzar la estación y bajar la temperatura; no existía ninguna relación clara entre la talla y la salinidad. De los 2.964 camarones capturados en el canal de paso de la marea, el 55,1 por ciento eran hembras, pero la proporción de sexos no se alejó mucho de 1:1.

1 INTRODUCTION

Adult white shrimp, Penaeus setiferus (Linnaeus), which contribute to the Texas commercial fishery, spawn offshore in the Gulf of Mexico. Peak postlarval immigration into Galveston Bay, Texas, occurs in the summer (Baxter and Renfro, 1967), and juveniles are most abundant from August to December (Chin, 1960; Baxter and Renfro, 1967). In general, juvenile and subadult white shrimp emigrate from the bay in the autumn as temperatures decrease. Shrimp that emigrate to outside waters appear to remain adjacent to the estuaries until adverse environmental changes force them offshore or possibly until water temperature in the estuary rises enough to allow the shrimp to move back into the bays (Lindner and Anderson, 1956).

Specific information on causes of emigration is needed to gain a clear understanding of the life history. In addition, information on the size and time of emigration can be used in regulating the shrimp fishery. The objectives of this study are to determine for juvenile and subadult white shrimp emigrating from Galveston Bay: (1) vertical distribution; (2) peaks of emigration; (3) sex ratio; (4) size at emigration; and (5) the effects of temperature and salinity on size and abundance.

2 METHODS

2.1 Study Area

Galveston Bay in southeast Texas is connected with the Gulf of Mexico by three tidal passes (Fig. 1a and 1b). The Bolivar Roads tidal pass was chosen for studying white shrimp emigration because about 85 percent of the tidal exchange occurs through it (Trent, 1967b). Water depths (mean low tide) at sampling stations 1 and 2 (Fig. 1c) were about 8 and 10 m respectively.

2.2 Gear and Sampling Procedure

Sampling for shrimp was conducted in the tidal pass from 1 August 1966 to 27 January 1967. Intervals between sampling dates were usually 3 or 4 days, but were shorter during periods when water temperature dropped rapidly in Galveston Bay.

An otter trawl with an opening of 1.2 by 3.0 m was used for sampling. Five corks were attached to the float line and a chain to the foot line of the trawl. The cotton webbing had stretched mesh of 38 mm in the body and 28 mm in the cod end.

Samples were taken at three depths in the water column. Fishing depth of the trawl was controlled by making slight alterations in the otter boards or length of towing line. Standard otter boards were used for sampling at the bottom and in midwater, and converted otter boards (Trent, 1967a) for sampling at the surface. To sample in midwater, only enough towing rope was paid out to permit the trawl to fish 3.7 to 4.9 m below the surface.

The samples were taken by towing the trawl from a 12-m vessel at a constant engine speed. Most samples were taken during the day within 2 h of maximum ebb tide or during ebb tides within 24 h after strong northerly winds. Catch per effort reported here included all white shrimp caught per 8-min tow against ebbing tides. Three tows were made at each depth on each collecting date.

In the Gulf (station 2), bottom tows were made on days following high catches in the tidal pass. Towing time varied from 10 to 30 min. Shrimp from these tows were measured for comparison with the length of shrimp caught in the tidal pass.

2.3 Measurements

Total length (tip of rostrum to tip of telson) of all shrimp caught was measured to the nearest half-centimeter immediately after capture. Mean total lengths were calculated from length-frequency distributions. Sex was determined for all shrimp caught in the tidal pass.

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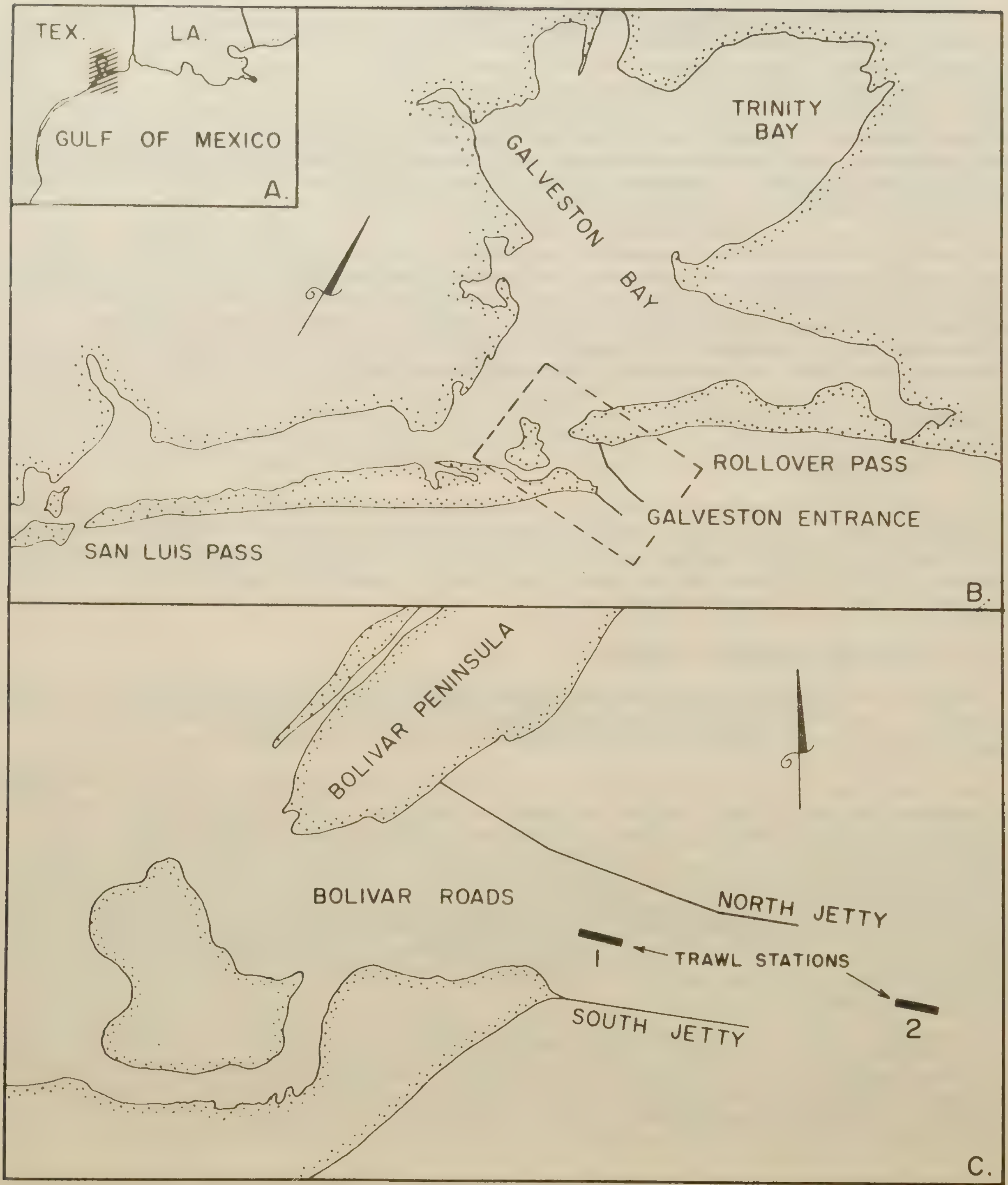
TEX.
LA.
GULF OF MEXICO
A.
GALVESTON BAY
TRINITY BAY
ROLLOVER PASS
GALVESTON ENTRANCE
SAN LUIS PASS
B.
BOLIVAR PENINSULA
BOLIVAR ROADS
NORTH JETTY
1
TRAWL STATIONS
2
SOUTH JETTY
C.

Fig. 1 Galveston Bay and Bolivar Roads tidal pass showing locations of stations at which trawl samples were taken.

2.4 Hydrology

Salinity to the nearest 0.1^{o}/oo (determined by titration) and temperature to the nearest 0.5^{o}C were measured from a surface-water sample taken at the tidal pass station on each sampling date. Air temperatures were obtained from "Local Climatological Data" for Galveston, Texas, U.S. Weather Bureau.

3 VERTICAL DISTRIBUTION

Catch of emigrating white shrimp by depth and sampling date are given in Table I. The mean numbers of shrimp caught at each depth were compared by analysis of variance. Before analysis, however, catch values were transformed to Log 10 (number caught + 1). Data from sampling dates on which no shrimp were caught, and samples taken at night were not included in the analysis. The analysis of variance indicated a significant difference in catch per unit of effort between depths (Table II).

Duncan's Multiple Range Test indicated that catch per unit of effort increased significantly from surface to bottom (Table III). The values of transformed mean catch per tow tested were: surface, 0.1288; midwater, 0.4974; and bottom, 0.7408. Shrimp were caught in large numbers in surface tows on 19 October and 2 November, but were absent in the surface tows on all other sampling dates (Table I). High tidal velocity and extremely turbid water on these two dates possibly accounted for the occurrence of shrimp in the surface waters.

4 PEAKS OF EMIGRATION

Air and water temperatures, salinity, and the mean number of shrimp caught per tow (depths combined) are presented in Fig. 2. In general, temperatures decreased during the season, whereas salinity showed no definite seasonal trend. Extreme drops in temperature did, however, usually correspond with extreme drops in salinity. This relation is explained by the occurrence of cold north winds, reflected in air temperature, causing a decrease in water temperatures in the bay and forcing cold, low-salinity bay water through the passes.

Peaks of white shrimp emigration were correlated closely with rapidly decreasing temperatures and salinities (Fig. 2). The relation between temperature and emigration agrees with the findings of Lindner and Anderson (1956) who stated that large juvenile and subadult white shrimp move to warmer water (the Gulf of Mexico in our study) as a result of falling temperatures in estuaries. Our first peak of emigration occurred 19 October, when daily mean water temperature dropped from 24° to 19°C. The next three peaks of emigration coincided also with drops in temperature. For the rest of the season, however, the relation is not clear, probably because temperature changes were not as great and because emigration was more nearly constant. White shrimp emigration occurred at tidal pass temperatures between 19^{o} and 8^{o}C.

5 SIZE AT EMIGRATION

The number and mean total length of all white shrimp taken in the tidal pass by date, water depth, and sex are shown in Table IV. The numbers of shrimp shown in Table I disagree with the numbers shown in Table IV because additional trawl samples, not included in Table I, were taken on 19 October, 2 November, 11 December and 4 January.

The mean lengths of shrimp caught in surface, midwater, and bottom tows on 19 October and 2 November (the only dates on which shrimp were taken at the surface) were compared by analysis of variance (Table V), and mean lengths of shrimp caught in midwater and bottom tows were compared by using a paired comparison t-test ($t = 1.99$; $t_{.05} = 2.31$ for 8 d.f.). The t-test was also used to compare mean lengths of males and females ($t = 1.27$; $t_{.05} = 2.20$ for 11 d.f.). Samples in which less than 10 shrimp were caught for each depth or for each sex were not used. No significant differences were found.

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TABLE I

Number of white shrimp caught per 8-min tow on ebbing tides in Bolivar Roads tidal pass (August 1966 – January 1967)

Date	Depth of tow			Date	Depth of tow		
	Surface	Midwater	Bottom		Surface	Midwater	Bottom
Aug. 1*	0	0	0	22	0	0	0
	0	0	0		0	0	0
	0	0	0		0	0	0
3*	0	0	0	26*	0	0	0
	0	0	0		0	0	0
	0	0	0		0	0	0
8	0	0	0	29*	0	0	0
	0	0	0		0	0	0
	0	0	0		0	0	0
11*	0	0	0	Oct. 3	0	0	0
	0	0	0		0	0	1
	0	0	0		0	1	0
15*	0	0	0	7	0	1	0
	0	0	0		0	0	0
	0	0	1		0	0	0
18*	0	0	0	11*	0	1	1
	0	0	0		0	0	0
	0	0	0		0	0	0
22	0	0	0	13	0	0	0
	0	0	0		0	0	0
	0	0	0		0	0	0
26*	0	0	2	19	16	15	15
	0	1	2		20	35	12
	0	0	3		10	2	10
29*	0	0	0	20	0	0	3
	0	0	0		0	0	0
	0	1	0		0	0	1
Sept. 1*	0	0	0	24*	0	0	0
	0	0	0		0	1	0
	0	0	0		0	0	0
6	0	0	0	27	0	0	0
	0	0	0		0	0	1
	0	0	0		0	0	0
12*	0	0	0	31	0	0	0
	0	0	0		0	0	0
	0	0	0		0	0	0
15	0	0	0	Nov. 2	153	26	85
	0	1	0		269	113	65
	0	0	0		163	22	75

Contd

TABLE I (contd)

Date	Depth of tow			Date	Depth of tow		
	Surface	Midwater	Bottom		Surface	Midwater	Bottom
Nov. 3	0	36	1	12	0	23	25
	0	6	13		0	54	41
	0	18	11		0	12	41
7	0	1	5	15	0	0	7
	0	0	2		0	0	1
	0	1	2		0	0	1
10	0	1	3	17	0	0	22
	0	5	1		0	0	27
	0	0	2		0	0	20
14	0	0	1	22	0	0	0
	0	0	1		0	0	3
	0	1	1		0	0	1
18	0	0	0	23	0	5	24
	0	0	1		0	3	48
	0	0	0		0	86	44
21*	0	0	0	28	0	15	8
	0	0	0		0	30	24
	0	0	1		0	10	23
25	0	1	1	30	0	1	44
	0	1	4		0	0	18
	0	5	6		0	0	51
28	0	330	11	Jan. 3*	0	2	5
	0	13	12		0	3	4
	0	24	7		0	6	4
30	0	1	2	6	0	0	0
	0	0	0		0	0	7
	0	1	1		0	0	1
Dec. 2	0	0	0	9	0	4	6
	0	0	0		0	3	4
	0	0	0		0	13	5
5	0	1	3	12	0	0	1
	0	0	2		0	0	0
	0	1	2		0	1	0
8	0	0	6	18	0	0	3
	0	2	1		0	0	0
	0	1	2		0	0	0
11	0	10	14	27	0	0	2
	0	8	23		0	0	4
	0	14	64		0	1	2
				Total	631	974	1,004

* Night samples

TABLE II

Analysis of variance of the mean number of shrimp caught per tow (transformed values) between water depths

Source of variation	d.f.	Sum of squares	Mean square	F.
Between depths	2	15.38255	7.69127	24.49*
Within depths	240	75.37036	0.31400	
Total	242	90.75291		

* Significant at the 99-percent level

TABLE III

Duncan's multiple range comparison of the mean number (means of transformed values) of shrimp caught in surface, midwater, and bottom tows

Comparison between		$x_a - x_b$	Least significant range
a	b		
Bottom	Surface	0.612	0.237*
Bottom	Midwater	0.243	0.227*
Midwater	Surface	0.369	0.227*

* Significant at the 99-percent level

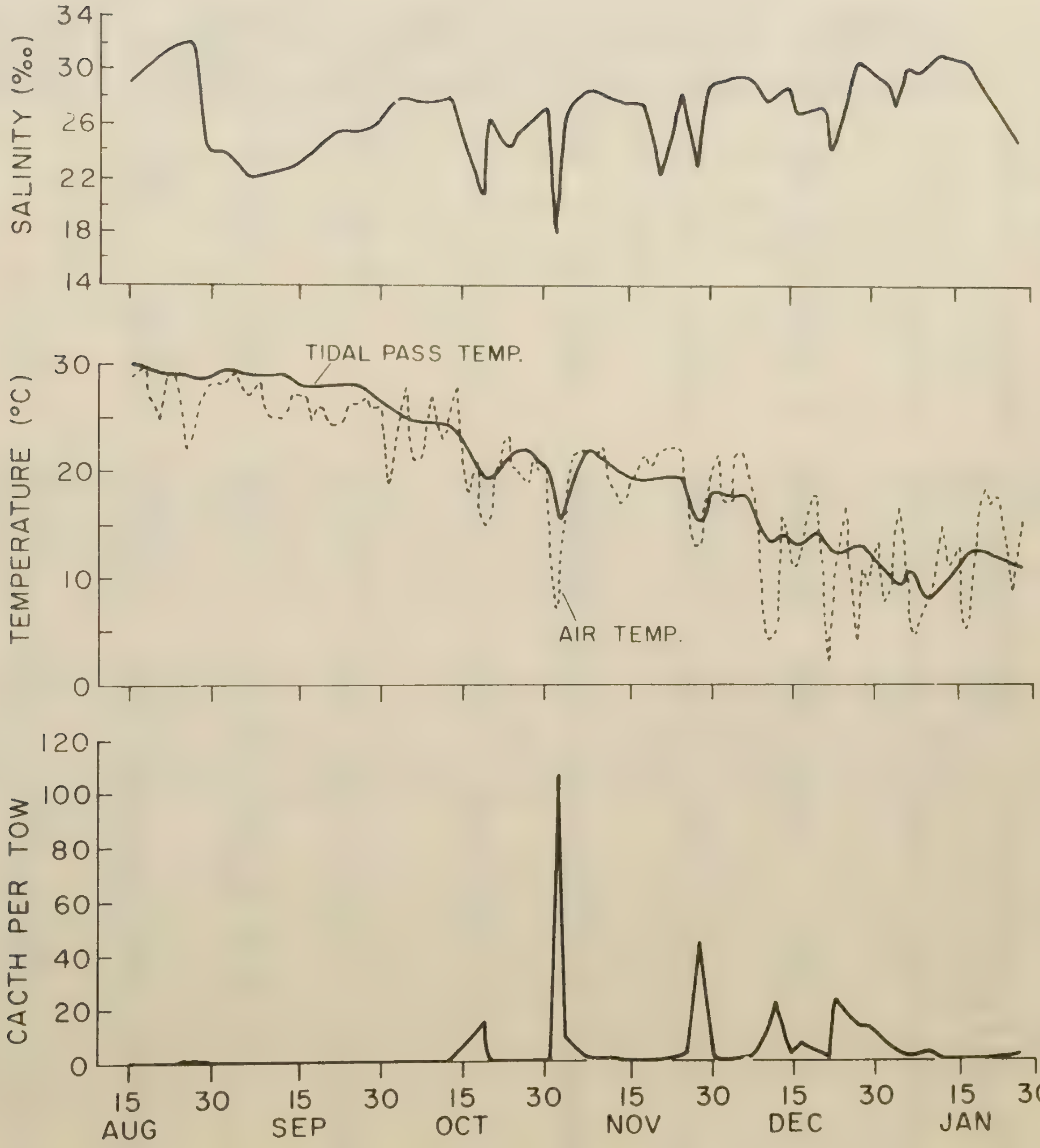

Fig. 2 Abundance of white shrimp caught in Bolivar Roads tidal pass as related to salinity and temperature.

TABLE IV

Mean total length in millimeters of white shrimp, by date, water depth, and sex

Date	Midwater		Bottom		Male		Female		All shrimp	
	No. of shrimp	Mean length	No. of shrimp	Mean length	No. of shrimp	Mean length	No. of shrimp	Mean length	No. of shrimp	Mean length
Aug. 5	0		1	135	1	135	0		1	135
26	1	140	7	147	5	144	3	150	8	146
29	1	160	0		0		1	160	1	160
Sept. 15	1	160	0		1	160	0		1	160
Oct. 3	1	160	1	70	1	160	1	70	2	115
7	1	155	0		0		1	155	1	155
11	1	150	1	135	0		2	142	2	142
19*	67	125	138	114	97*	120	178*	119	275*	119
20	0		4	112	3	98	1	155	4	112
24	1	110	0		0		1	110	1	110
27	0		1	110	1	110	0		1	110
Nov. 2**	194	98	258	94	485**	98	612**	95	1097**	96
3	60	123	25	123	46	123	39	124	85	123
7	2	97	9	105	5	102	6	106	11	104
10	6	98	6	107	5	96	7	107	12	102
14	1	100	3	102	3	100	1	105	4	101
18	0		1	120	1	120	0		1	120
21	0		1	120	1	120	0		1	120
25	7	113	11	116	12	116	6	112	18	115
28	367	100	30	98	214	100	183	99	397	100
30	2	102	3	98	3	100	2	100	5	100
Dec. 5	2	117	7	103	3	102	6	108	9	106
8	3	97	9	98	6	96	6	99	12	97
11	62	94	149	95	88	94	123	95	211	94
12	89	90	107	91	93	91	103	90	196	91
15	0		9	102	5	100	4	105	9	102
17	0		69	101	29	103	40	99	69	101
22	0		4	108	1	105	3	108	4	107
23	94	93	116	92	87	94	123	91	210	92
28	55	87	55	85	36	87	74	85	110	86
30	1	75	113	90	50	91	64	89	114	90
Jan. 3	13	94	11	87	12	87	12	94	24	91
4	2	95	9	95	6	93	5	97	11	95
6	0		8	91	5	90	3	93	8	91
9	20	92	15	88	16	93	19	88	35	90
12	1	65	1	85	1	65	1	85	2	75
18	0		3	93	3	93	0		3	93
27	1	100	8	98	6	97	3	100	9	98
Totals and weighted means	1056	100	1193	97	1331	99	1633	98	2964	99

* 70 shrimp having a mean length of 123 mm caught in surface tows.

** 645 shrimp having a mean length of 96 mm caught in surface tows.

TABLE V

Analysis of variance of the mean lengths of shrimp caught in surface, midwater, and bottom tows on 19 October and 2 November 1966

Source of variation	d.f.	Sum of squares	Mean square	F
Between depths	2	378.5433	189.2717	1.12
Within depths	21	3,547.2550	168.9169	
Total	23	3,925.7983		

Although lengths did not differ between either sexes or depths, mean lengths decreased during the study period. To illustrate this decrease, we plotted mean lengths against time and fitted a non-weighted linear regression to the data (Fig. 3). The null hypothesis that the mean sizes were similar at different times was rejected ($t = 9.50$; $t_{.01} = 2.90$ for 36 d.f.). Size at emigration decreased significantly during the study (Fig. 3) and closely followed decreasing water temperatures (Fig. 2).

Length-frequency distributions of white shrimp caught each week in the tidal pass and in the Gulf of Mexico are shown in Fig. 4. Only data from those weeks in which at least 30 shrimp were caught in each of the two areas (except for 8 - 14 January) are included. The mean length of shrimp caught in the Gulf was greater than the mean length of shrimp caught in the tidal pass for each week. Variation in length (both in the pass and Gulf) was greater 16 - 22 October and 30 October to 5 November than in the other weeks.

White shrimp, after emigrating from estuarine areas, tend to remain near shore or to migrate alongshore unless low temperatures force them offshore (Lindner and Anderson, 1956). If this situation existed during our study, possible components of the population that we sampled in the Gulf were (1) recent emigrants from Galveston Bay, (2) shrimp which emigrated from Galveston Bay over the entire emigration period, (3) shrimp which emigrated from other estuaries and moved alongshore to our Gulf station, and (4) shrimp which migrated to the sampling area from offshore. Consequently, we would expect that samples taken in the Gulf would be composed of larger shrimp than samples taken in the tidal pass if any of the last three components were included in the Gulf population sampled.

6 SEX RATIO

Of 2,964 white shrimp caught in the tidal pass (Table IV), 1,633 (55.1 percent) were females. A chi-square test indicated that the sex ratio did not deviate from a 1:1 ratio ($\chi^2 = 46.4$ with 37 d.f., $\chi^2_{.10} = 48.3$).

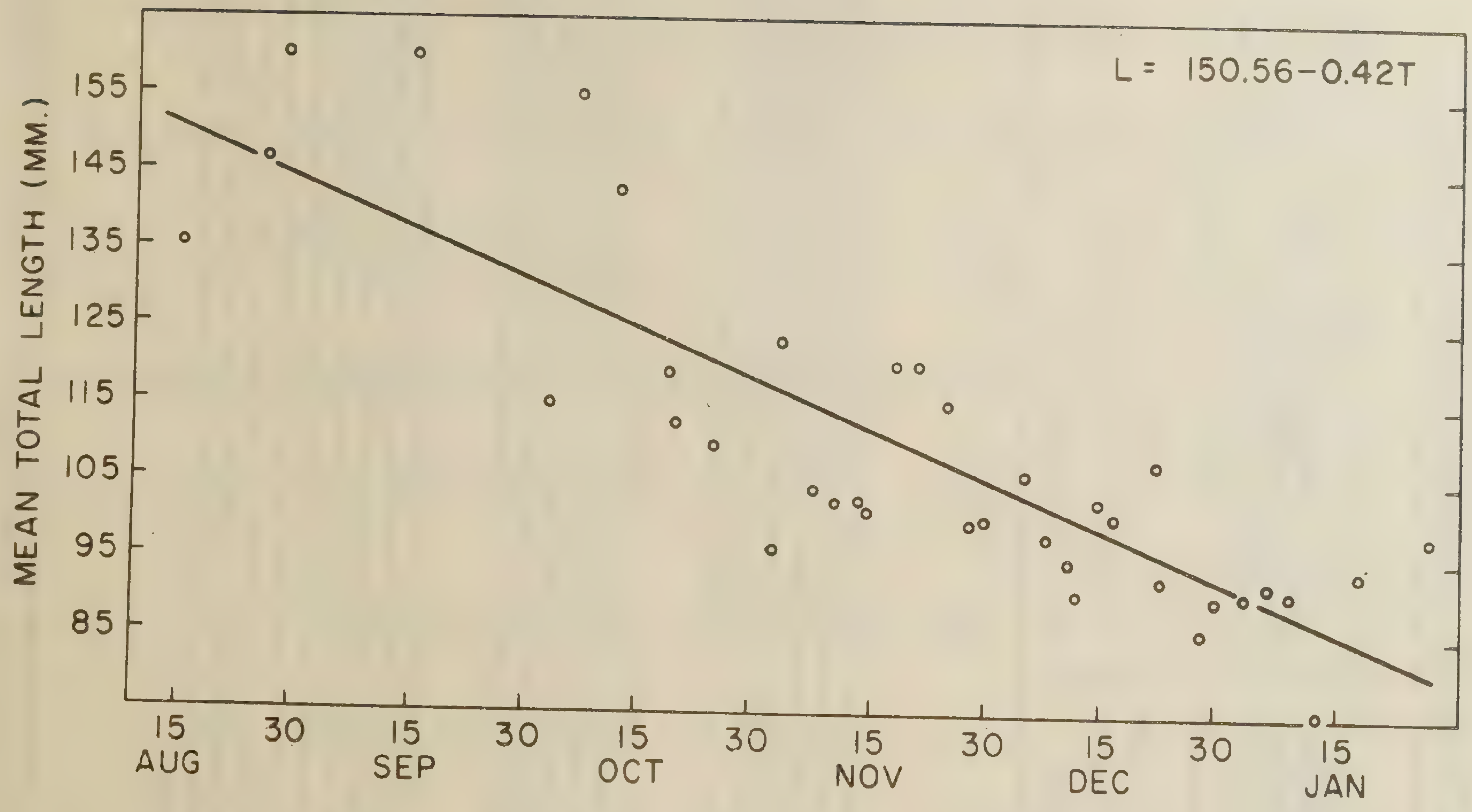

Fig. 3 Decrease in mean length of white shrimp caught in the Bolivar Roads tidal pass, 15 August 1966 to 27 January 1967.

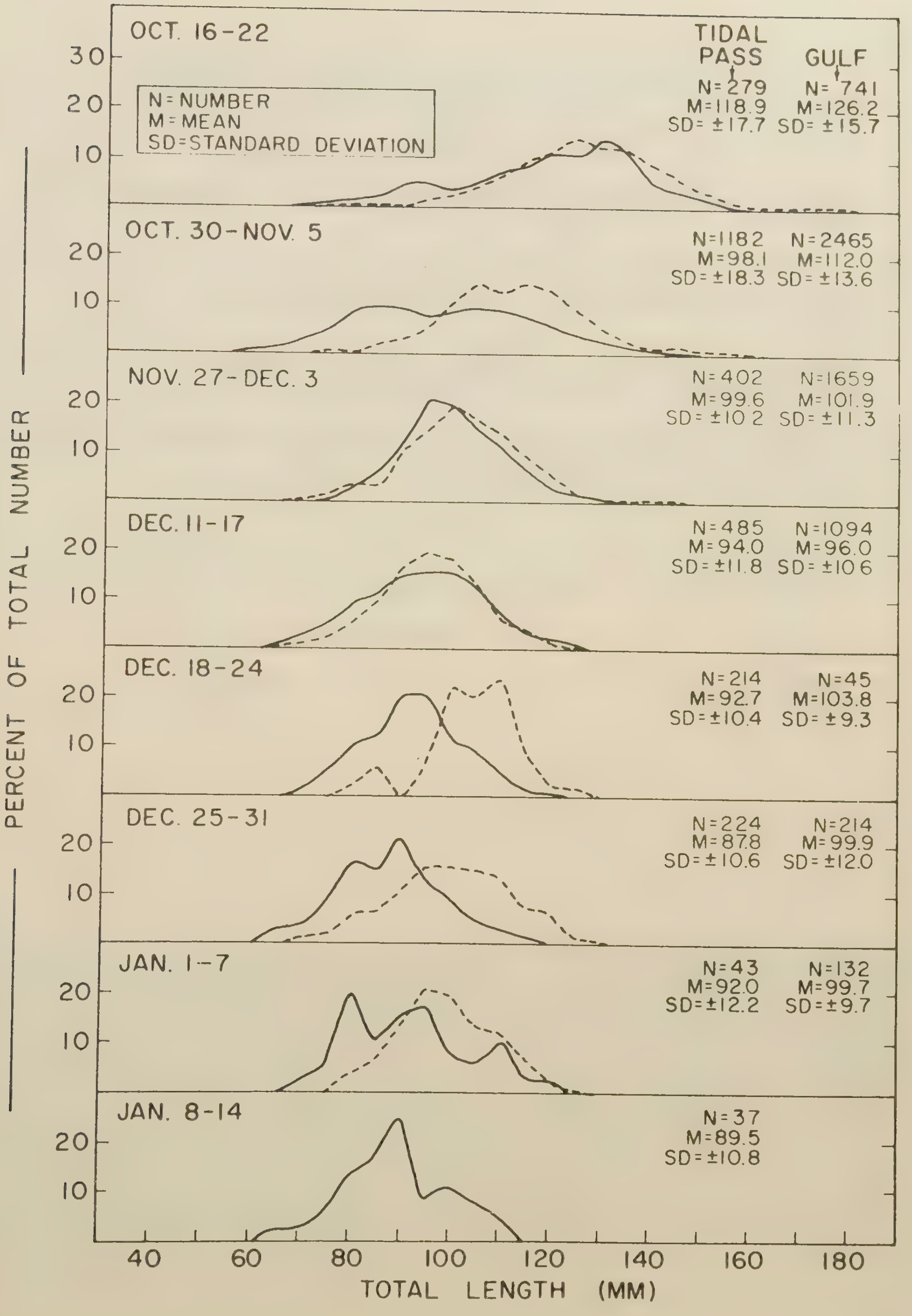

Fig. 4 Length-frequency distributions by week of white shrimp caught in the Bolivar Roads tidal pass (solid line) and in the Gulf of Mexico (broken line).

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E/59

AN APPRAISAL OF THE EFFECTS OF SALINITY AND TEMPERATURE ON GROWTH AND SURVIVAL OF POSTLARVAL PENAEIDS [1]

by

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Abstract

Growth and survival experiments conducted in the laboratory on postlarval *Penaeus aztecus* Ives and *P. setiferus* (Linnaeus) showed that, in general, both species tolerated a broad range of temperature and salinity, but some differences between species existed. At specific temperatures which ranged from 11° to 35°C, *P. aztecus* was more tolerant than *P. setiferus* of temperatures of 15°C or lower. In contrast, *P. setiferus* was more tolerant than *P. aztecus* at 30° to 35°C. Test salinities between 2 and 40‰ showed that *P. aztecus* tolerated higher salinities than did *P. setiferus*. Specific combinations of salinity and temperature were tested to determine whether these factors interacted to affect postlarval shrimp. Combinations of low temperature and low salinity were detrimental. The effects of salinity and temperature on growth, survival, and tolerances of postlarvae as observed in the laboratory are discussed as related to overwintering of postlarval *P. aztecus*; rate of growth as observed in nature; time of entry of the two species into the nursery areas; and the effects of simultaneous decrease of salinity and temperature.

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E/59

EVALUATION DE L'EFFET DE LA SALINITE ET DE LA TEMPERATURE SUR LA CROISSANCE ET LA SURVIE DES POSTLARVES DE PENAEIDAE

Résumé

Des expériences de laboratoire conduites sur des postlarves de Penaeus aztecus Ives et de P. setiferus (Linnaeus) du point de vue de la croissance et de la survie ont révélé que, dans l'ensemble, ces deux espèces s'accommodaient d'une gamme étendue de températures et de salinités, tout en accusant certaines différences. Durant une épreuve comportant l'exposition à diverses températures échelonnées de 11° à 35°C, P. aztecus a manifesté une plus grande tolérance que P. setiferus jusqu'à 15°C tandis que de 30° à 35°C c'est le contraire qui s'est produit. Au cours d'expériences durant lesquelles le taux de salinité a varié de 2 à 40 °/oo, P. aztecus a mieux supporté les salinités élevées que P. setiferus. Diverses combinaisons de salinité et de température ont été expérimentées afin de déterminer si l'action conjugée de ces facteurs jouait un rôle dans le développement des postlarves. On a noté l'effet nocif de la combinaison basse température et basse salinité. Les incidences de la salinité et de la température sur la croissance et la survie ainsi que les divers degrés de tolérance des postlarves constatés au laboratoire sont examinés des points de vue suivants: hivernage des postlarves de P. aztecus, taux de croissance à l'état naturel; époque de pénétration des deux espèces dans les zones de développement des jeunes; et conséquences d'une baisse simultanée de la salinité et de la température.

EVALUACION DE LOS EFECTOS DE LA SALINIDAD Y LA TEMPERATURA EN EL CRECIMIENTO Y SUPERVIVENCIA DE LOS PENEIDOS POSTLARVALES

Extracto

Los experimentos sobre crecimiento y supervivencia realizados en el laboratorio con formas postlarvales de Penaeus aztecus Ives y P. setiferus (Linnaeus) indicaron que, en general, ambas especies toleraban un amplio margen de temperatura y salinidad, pero que existían algunas diferencias entre ambas. A temperaturas específicas que oscilaban de 11° a 35°C, P. aztecus era más tolerante a las temperaturas de 15°C o más bajas, que P. setiferus. En cambio, P. setiferus toleraba mejor que P. aztecus las temperaturas de 30° a 35°C. Las salinidades de ensayo entre el 2 y el 40 por mil indicaron que P. aztecus toleraba salinidades más elevadas que P. setiferus. Se ensayaron combinaciones específicas de salinidad y temperatura para determinar si la interacción de estos factores influía en los camarones postlarvales. Las combinaciones de baja temperatura y poca salinidad eran perjudiciales. Se examinan los efectos observados en el laboratorio de la salinidad y la temperatura sobre el crecimiento, supervivencia y tolerancias de las formas postlarvales, en relación con la supervivencia en el transcurso del invierno de las postlarvas de P. aztecus; el ritmo de crecimiento tal como se observa en la naturaleza; el período de entrada de las dos especies en las zonas de cría; y los efectos de la disminución simultánea de la salinidad y la temperatura.

1 INTRODUCTION

The general life history of the three species of Penaeus, which are of commercial value to the North American shrimp fishery, is well known. The animals hatch and undergo the first stages of development in a relatively stable environment - the open ocean. The succeeding stage, in which growth is most rapid, is spent in a relatively unstable environment - the estuary. Then the animal returns to the open sea to spawn (Williams, 1965).

Observations made in the field suggest that the three species - P. aztecus Ives, the brown shrimp; P. duorarum Burkenroad, the pink shrimp; and P. setiferus (Linnaeus), the white shrimp - have somewhat different tolerances or preferences for certain environmental factors (Williams, 1965; Broad, 1965). These observations, however, leave many questions unanswered. We may well ask whether it is salinity alone, or the factors which accompany decreasing salinity (vegetation, fauna, light penetration, substrate type) that influence the distribution of the species. Again, how does temperature affect each species? Do salinity and temperature interact to limit the population? Do they affect the species in the same way at all seasons of the year? Are all age groups within a species affected by the environment in the same way?

We have chosen to study these questions through controlled laboratory experiments. Although conditions in these experiments do not closely approach those of the natural environment, they do permit the isolation of single factors.

2 METHODS

Our methods have been fully described in several papers (Zein-Eldin, 1963; Zein-Eldin and Aldrich, 1965; Zein-Eldin and Griffith, 1966) and are given only briefly here.

We have conducted two types of experiments. In the first type, individual survival was the sole criterion for the suitability of the environment. These survival experiments required less than 48 h - 12 to 24 h for changing the experimental conditions (acclimation), and 24 h for testing. Because acclimation changes in such experiments were rapid and drastic, resulting data were used to delimit the extremes of species tolerance and to guide us in further studies. Most of our studies have been done with postlarvae although juveniles and subadults also have been tested.

In the second type of study, the acclimation period was lengthened to about 48 to 72 h, and the animals were exposed to test conditions for about 1 mo. The mean increase in size of the animals was used as the index of the suitability of the environment.

For these experiments, postlarvae were collected from tidal passes and held in a storage tank for at least 24 h before testing. We usually placed 100 animals in each experimental tank - a standard 65-l glass aquarium with a subsurface filter covered with sterilized ground oyster shell and sand (Zein-Eldin, 1963). Tank water was initially 25‰ salinity. Salinity adjustments, when required, were made with distilled water or with concentrated sea water. Temperature adjustments were made in one of four constant temperature rooms or in B.O.D. - type incubators. Light also could be controlled in these chambers, but unless specified, all experiments were conducted under continuous fluorescent light.

Several foods were tested: a brown and a blue-green alga, ground fish, ground shrimp, live nauplii of the brine shrimp Artemia salina, and a combination of live brine shrimp and algae (Zein-Eldin, 1963). Animal food was necessary for the best growth. The presence of an excess of ground food, however, soon caused the tanks to foul. As a result, we fed only measured amounts of live brine shrimp.

At 5-day intervals, we removed 10 animals from each experimental tank. Each individual was dried in a soft paper towel, weighed to the nearest 0.1 mg with a semiautomatic balance, and measured (rostrum-telson length) to the nearest 0.5 mm.

3 EFFECTS OF ENVIRONMENTAL FACTORS

3.1 Salinity

Salinity is the factor most commonly correlated with abundance of juvenile and subadult penaeids (Gunter, 1950; Gunter, 1961a, 1961b; Gunter, Christmas and Killebrew, 1964; Williams, 1965; Broad, 1965). It has been suggested that the abundance of shrimp is greatest in low salinity, and that the smallest animals occur in the lowest salinities (Gunter, 1950). Frequently, this relation has been interpreted to mean that very low salinities are necessary for young shrimp to survive in the estuaries. The salinity varies in estuarine waters of Texas, depending upon season and year, from almost fresh (e.g. Trinity River delta; data from estuarine program of the Galveston Biological Laboratory) to the hyper-salinities (45$^{0}/_{00}$ and above) of Laguna Madre (Simmons, 1957). Young shrimp occur in all of these areas.

Because of the apparent importance of salinity, our first experiments were designed to assess the salinity requirements of P. aztecus. The results indicated that, at temperatures of 23-25°C and with food supplied in excess, postlarvae grew equally well at salinities of 2 to 40$^{0}/_{00}$; survival was 90-100 percent (Zein-Eldin, 1963). Our earliest conclusion, therefore, was that low salinity was neither a requirement for nor a detriment to either growth or survival of postlarval brown shrimp.

3.2 Temperature

Field observations concerning the effects of temperature upon penaeid shrimp are relatively few. Most articles discuss low temperature only (Gunter and Hildebrand, 1951). To determine temperature effects on postlarval brown and white shrimp, we exposed postlarvae to constant temperatures of 15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0, 32.5, and 35.0°C for 1 mo.

In these experiments, groups of 20 postlarvae were held in 4-1 glass aquaria. Five groups were held at each temperature, without light.

Responses of P. aztecus and P. setiferus to temperatures below 25°C, were different (Fig. 1). Growth rate of P. aztecus increased rapidly between 15 and 20°C; continued to increase, but at a slower rate, between 20 and 25°C. At 35°C, not only did growth rate decrease, but no animals survived more than 15 days (Zein-Eldin and Griffith, 1966).

The growth of P. setiferus increased at almost a constant rate with temperatures between 15 and 25°C (Griffith and Zein-Eldin, MS). Growth rate decreased between 32.5 and 35°C, so that postlarval P. setiferus reared at 35°C were about the same size as animals reared at 22.5°C.

Although growth of P. setiferus was the same at temperatures of 25-32.5°C in this series of experiments, other experiments performed in larger tanks (Zein-Eldin and Griffith, MS) suggested that increasing temperature continued to stimulate growth at temperatures greater than 25°C. Tank size or population density, or both, may affect growth rate (Zein-Eldin and Griffith, 1966). It is possible, therefore, that growth of P. setiferus increases with temperature at least to 32.5°C (Zein-Eldin and Griffith, MS).

The gross tissue production (total weight of tissue produced by all shrimp surviving the conditions for 1 mo) is another measure of the suitability of the environment. Because both the mean size of the survivor and the percentage survival are considered, it may be used to compare conditions in which a few large animals survive

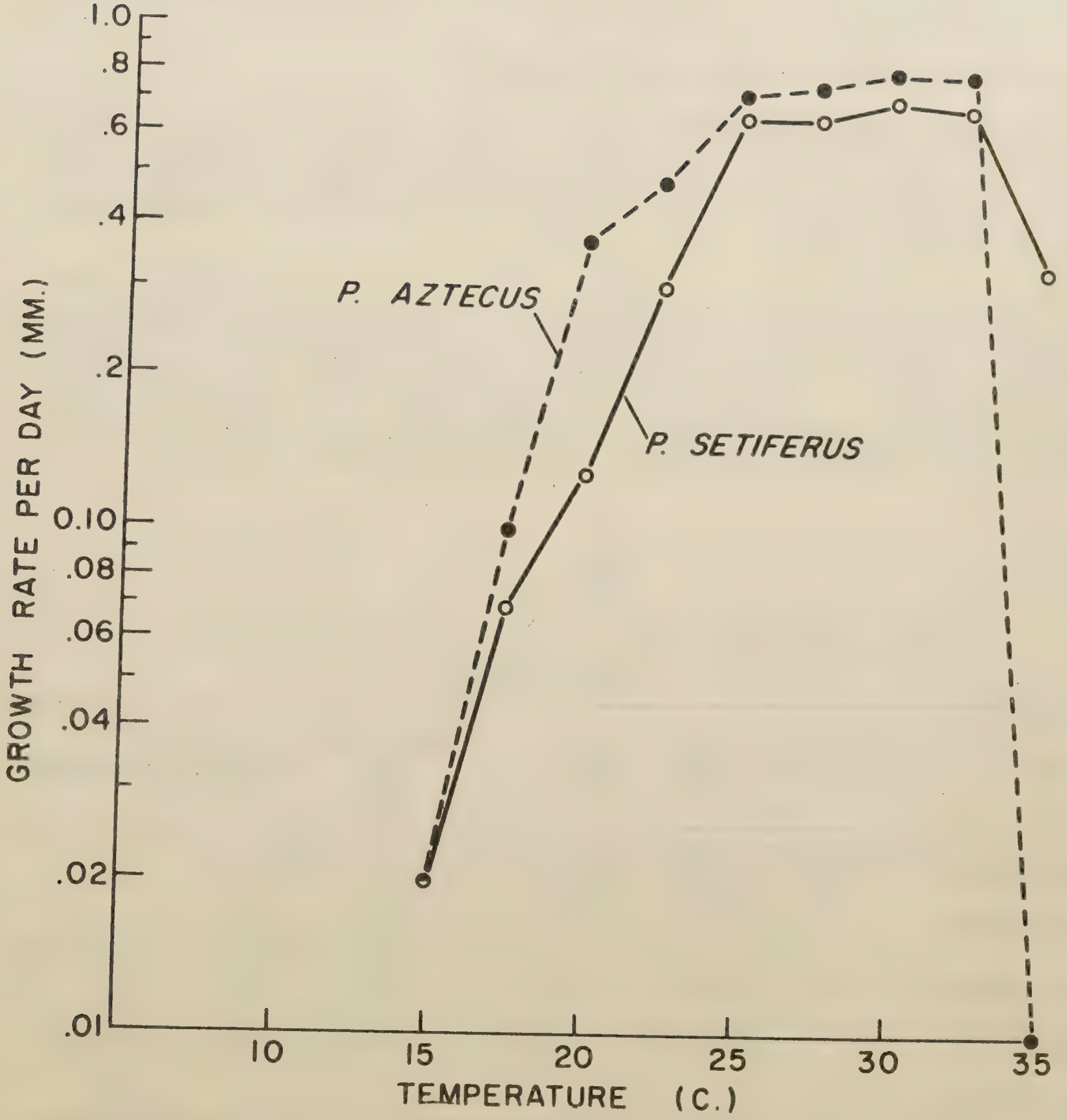

Fig. 1 Growth rate (mm/day) of two species of postlarval penaeids exposed to various temperatures (data for P. aztecus from Zein-Eldin and Griffith, 1966; for P. setiferus, Griffith and Zein-Eldin, MS).

with those in which surviving individuals are smaller but more numerous. Comparisons of gross tissue production further emphasize the differential effect of temperature (Fig. 2). The production of *P. aztecus* tissue declined sharply at temperatures above 27.5°C but the production of *P. setiferus* tissue continued to increase. The difference was primarily caused by a decreased survival of *P. aztecus* at temperatures above 27.5°C (Zein-Eldin and Griffith, 1966).

3.3 Combinations of salinity and temperature

3.3.1 Short-term survival   Studies of 24-h survival in which percentage survival served as an indicator of tolerance have been conducted. Acclimation of the animals to test conditions, as previously reported, was rapid - completed in 12 to 24 h. For the lowest temperature (7.0°C) and salinity (2‰) tested, this acclimation represented a change of about 1.0°C per h, and a simultaneous decrease in salinity of about 1°/oo per h.

The data indicated that the two species differed not only in temperature tolerances, but also in salinity tolerances (Fig. 3). Between 80 and 100 percent of postlarval *P. aztecus* withstood 24-h exposure to temperatures as low as 4-5°C (depending upon the season of collection) if salinity was about 25‰; yet, 100 percent of the animals died within 6 h if the temperature was reduced to 2°C (G. W. Griffith, unpublished records). *P. setiferus* has a low temperature limit of about 7°C under these same salinity conditions. At the other temperature extreme, over 90 percent of postlarval *P. setiferus* survived 35°C, but all died at 37.5°C (Table I).

TABLE I

Constant temperature at which 80 percent of the animals survive

(Salinity, 25°/oo)

Species	Total length (mm)	Upper limit (°C)	Lower limit (°C)	Acclimation time (h)	Period of exposure (h)	References
Penaeus aztecus	10-15	34[1/]	5-6	12	24	2,3/
Penaeus aztecus	10-50	28[1/]	11-15[4/]	48	672	5,2/
Penaeus setiferus	8-12	>35<37.5	>7.5<10	12	24	3/
Penaeus setiferus	8-50	>32.5<35	15 - 17.5[1/]	48	672	5,6/
Penaeus setiferus	50-100	>35	<7.5	12	24	3/

1/ Estimated
2/ Zein-Eldin and Aldrich (1965)
3/ G. W. Griffith (unpublished data)
4/ Depends upon season at which postlarvae are caught
5/ Griffith and Zein-Eldin (MS)
6/ Zein-Eldin and Griffith (MS)

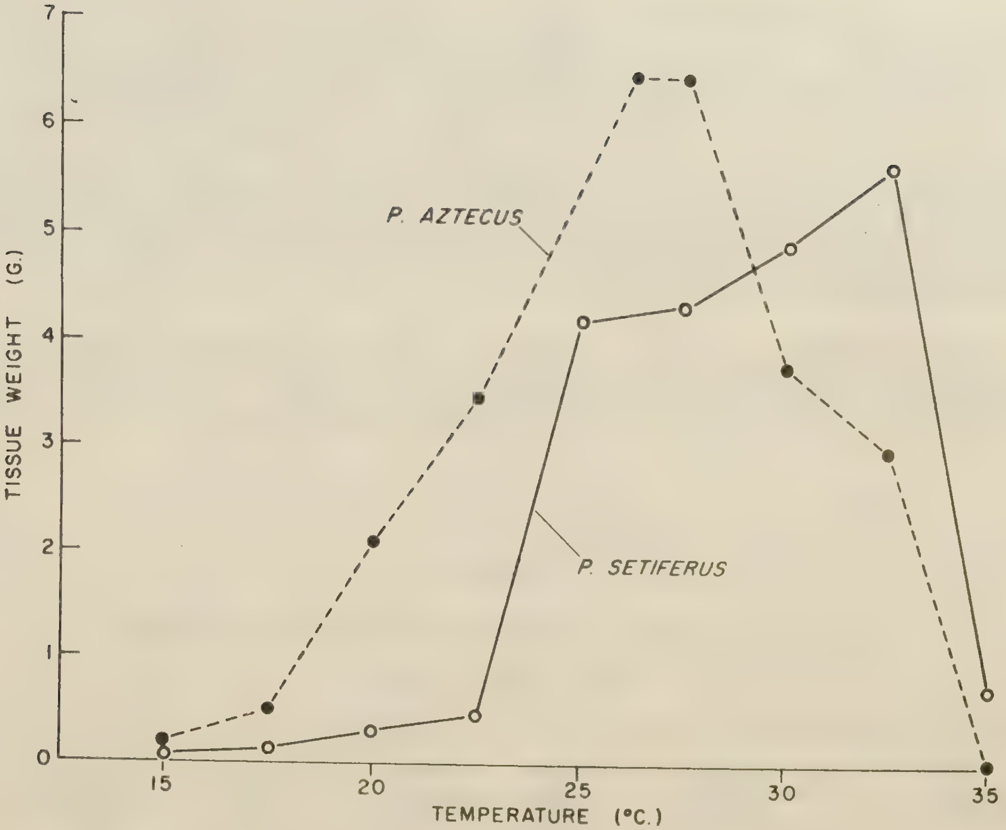

Fig. 2 Gross tissue production (g) by two species of postlarval penaeids exposed to various temperatures (data for P. aztecus from Zein-Eldin and Griffith, 1966; for P. setiferus, Griffith and Zein-Eldin, MS).

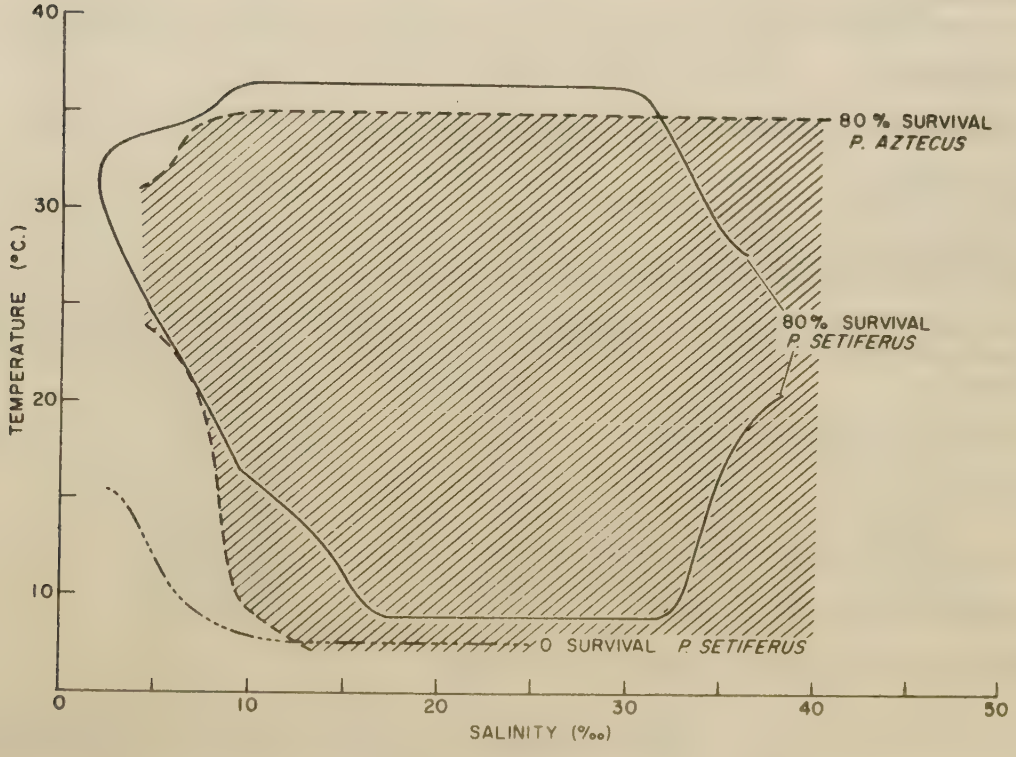

Fig. 3 Twenty-four h survival of two species of penaeids exposed to various combinations of salinity and temperature (data from Zein-Eldin and Aldrich, 1965; for P. setiferus, Griffith, unpublished).

3.3.2 One-month survival Survival in both species for 1 mo is somewhat less than that in the 24-h tests, in spite of a longer acclimation period (up to 4 days). P. setiferus, however, were able to withstand higher salinities in the 1-mo growth experiments than in the 24-h experiments. Low temperature, except at high salinities, apparently was less well tolerated by P. setiferus over a long period of time than over a short one. In P. aztecus, too, long exposure decreased survival under some experimental conditions. P. aztecus was generally less tolerant of the high temperatures (32 or 33°C) at all salinities. and did not survive combinations of low temperature (11°C) at salinities less than 15‰ (Zein-Eldin and Aldrich, 1965). Our data on the salinity and temperature survival limits of both P. aztecus and P. setiferus are summarized in Table I and II.

3.3.3 Growth The most extensive series of experiments which we have performed are those in which growth has been used as an index. We have tested P. aztecus and P. setiferus collected at various seasons of the year. Salinity and temperature combinations at which tests were made are listed in Table III.

TABLE II

Salinity at which 80 percent of the animals survive

(Temperature, 25°C)

Species	Total length (mm)	Upper limit (°/oo)	Lower limit (°/oo)	Acclimation time (h)	Period of exposure (h)	References
Penaeus aztecus	10-15	>40	<5	12	24	1/
Penaeus aztecus	10-50	>40	2 2/	48	672	1/
Penaeus setiferus	8-12	40 - 45	4 2/	12	24	3/
Penaeus setiferus	50-100	>40	<10	12	24	3/
Penaeus setiferus	8-50	>40	<2	48	672	4/
Penaeus setiferus	50-100	>54	4	672	1,344	5/

NOTE: Period of acclimation is apparently of extreme importance. We plan experiments to document this point. All above data refer to animals brought in from the sea.

1/ Zein-Eldin and Aldrich (1965)

2/ Estimated

3/ G. W. Griffith (unpublished data)

4/ Zein-Eldin and Griffith (MS)

5/ Griffith and Zein-Eldin (unpublished data)

Growth in both species was far more strongly affected by temperature at the same salinity than by salinity at the same temperature (Table IV). Little tissue was produced by either species at the lowest temperatures tested. Growth in postlarval *P. aztecus* increased markedly with temperature between 18 and 25°C (Fig. 4). Above 25°C, increasing temperature had much less effect on growth.

Growth in *P. setiferus* also increased between 18 and 25°C (Fig. 5). Temperature above 25°C continued to have a marked effect at salinities of 5 and 15°/oo. Thus, twice as much tissue was produced by postlarval *P. setiferus* at the intermediate salinities than at salinities of 25 and 35°/oo. Salinity also affected *P. aztecus* at 32.5°C; the most tissue was produced at 35°/oo (Fig. 4).

TABLE III

Salinity and temperature combinations tested

(W = *P. setiferus*; B = *P. aztecus*; 0 = no test made)

Temperature (°C)	(Salinity, °/oo)					
	2	5	15	25	35	40
11	W, B	W, B	W, B	W, B	W, B	0
15	0	W, B	0	W, B	0	W, B
18	W, B	W, B	W, B	W, B	W, B	0
25	W, B	W, B	W, B	W, B	W, B	0
32	W, B	W, B	W, B	W, B	W, B	0
33	0	W, B	0	W, B	0	W, B

TABLE IV

Increase in mean total length (mm) of two species of *Penaeus* postlarvae exposed for one month to various combinations of salinity and temperature 1/

(Initial length of *P. aztecus*, 12.1 mm; *P. setiferus*, 6.1 mm
0 = no survivors)

Salinity (°/oo)	Species	Temperature (° C)			
		32	25	18	11
2	*P. aztecus*	22.7	0	0	0
	P. setiferus	25.1	19.9	2.0	0
5	*P. aztecus*	27.5	21.8	6.2	0
	P. setiferus	27.9	14.0	2.3	0
15	*P. aztecus*	18.9	25.3	7.0	0.5
	P. setiferus	25.9	17.7	1.7	0
25	*P. aztecus*	31.0	23.1	8.0	0.6
	P. setiferus	22.5	18.4	2.5	0
35	*P. aztecus*	26.2	22.3	6.2	0.3
	P. setiferus	18.7	15.1	2.1	1.1

1/ *P. aztecus* data from Zein-Eldin and Aldrich, 1965
P. setiferus data from Zein-Eldin and Griffith, MS

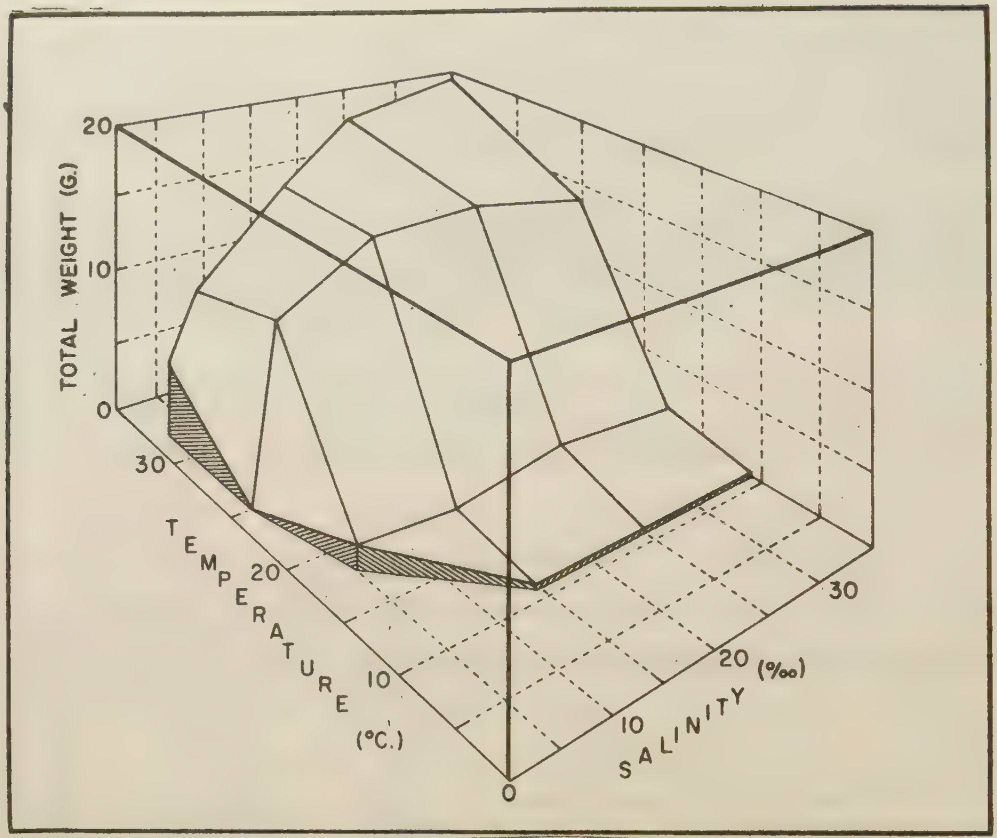

Fig. 4 Gross tissue production by *P. aztecus* postlarvae exposed to various conditions of temperature and salinity (data from Zein-Eldin and Aldrich, 1965).

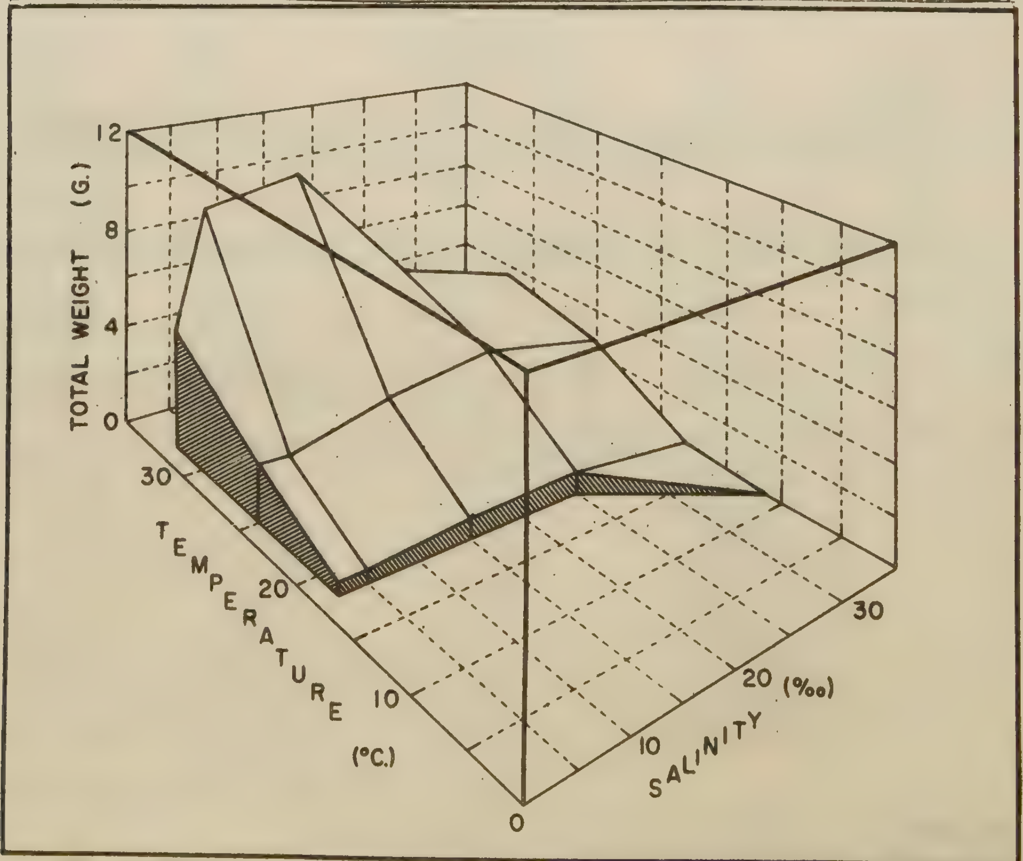

Fig. 5 Gross tissue production by *P. setiferus* postlarvae exposed to various conditions of temperature and salinity (data from Zein-Eldin and Griffith, MS).

4 ECOLOGICAL IMPLICATIONS

Species differences in temperature and salinity tolerance as shown in the laboratory may help explain life histories. Postlarval P. aztecus enter the Galveston Bay system in large numbers during February and March (Baxter, 1963; Baxter and Renfro, 1967). This group of postlarvae is apparently spawned during the autumn of the preceding year, and overwinters in the open Gulf of Mexico (Temple and Fischer, 1967). These postlarvae appear to have survived low temperatures, growing very little, for a period of about 4 mo. In the laboratory, it has been shown that postlarval P. aztecus can survive temperatures as low as 11°C for 1 mo at salinities of the open Gulf (Zein-Eldin and Aldrich, 1965). Growth is insignificant at these temperatures in the laboratory.

Following entry into the nursery areas, postlarval P. aztecus do not grow rapidly until water temperatures exceed 20°C (St. Amant, Corkum and Broom, 1963). Similarly, significant growth of laboratory-held postlarval P. aztecus occurs only at temperatures of 20°C and above (Fig. 1); growth approaches maximal at 25°C.

Laboratory studies have shown that combinations of low temperature and salinity are detrimental to postlarval P. aztecus. Similar conditions may occur during the winter and spring in the nursery areas or estuaries. If they occur after the entrance of the spring group of postlarval P. aztecus, they could be catastrophic to the population (Gulf States Marine Fisheries Commission, 1964).

The bulk of the postlarval P. setiferus population is probably not exposed to low temperature in nature. P. setiferus does not become abundant in Texas estuaries until May when water temperatures are well above 25°C, and few enter estuaries as late as November when water temperatures are below 20°C (Baxter and Renfro, 1967). Thus, the inability of the postlarval P. setiferus to withstand cold is probably less important to the species than the tolerance for temperatures of 30°C and above (Figs. 2, 3 and 5) - temperatures to which postlarvae may well be exposed in the shallow, marshy nursery areas during the summer.

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PREDICTION OF THE SUCCESS OF COMMERCIAL SHRIMP FISHING ON THE TORTUGAS GROUNDS BASED ON ENUMERATION OF EMIGRANTS FROM THE EVERGLADES NATIONAL PARK ESTUARY [1]

by

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Abstract

Studies have been underway since 1962 on the juvenile stages of the pink shrimp (Penaeus duorarum Burkenroad) in the Everglades National Park estuary. The objectives of this study have been to increase knowledge of the biology and migration of the shrimp and to determine if a relationship exists between the relative abundance of emigrating juveniles and the catches of adults on the Tortugas commercial fishing grounds.

From January 1963 through June 1965 the relative monthly abundance of juveniles was estimated from catches in Buttonwood Canal at Flamingo in Everglades National Park using a large "channel net". The entire canal was fished by this gear, which relied on tidal currents to collect samples. Subsequently experiments showed that "wing nets" could reliably subsample the shrimp moving in the canal, and all samples were thereafter taken with this gear.

Catches of juveniles made near the times of the new and full moon are used as indices of monthly abundance. These show a positive correlation with the commercial landings of the smallest size shrimp.

During periods of high abundance, when the average size of the emigrants is small (11 mm carapace length or smaller), there is a delay of 2 to 2-1/2 months from the time they leave the estuary until they appear in the commercial catches. In periods of high abundance, when the shrimp are larger, the delay between the estuary and the commercial catch is reduced to one month. Growth rates suggest that the differences in migration times are caused by a delay in the arrival of the shrimp at a size large enough for the

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trawls to capture. When an appropriate time lag is used the correlation is improved between the relative abundance of emigrating juveniles and the catch per unit of effort of small shrimp on the Tortugas grounds. Based on this relationship a forecast of increased abundance of small shrimp on the fishing grounds can be made before they are available to the fishery.

Using commercial landing data an apparent movement through the Tortugas fishery can be seen. This appears reliable enough that a forecast of up to 4 months can be made of increased abundance of 41 - 50 count shrimp.

PREDICTION DES RESULTATS DE LA PECHE COMMERCIALE DE LA CREVETTE SUR LES FONDS DES TORTUGAS, D'APRES LE COMPTAGE DES SUJETS EMIGRANT DE L'ESTUAIRE DU PARC NATIONAL DES EVERGLADES

Résumé

L'étude, menée depuis 1962, sur les stades juvéniles de la crevette Penaeus duorarum Burkenroad vivant dans l'estuaire du Parc national des Everglades, se propose d'accroître les connaissances sur la biologie et les déplacements de ce crustacé, et de déterminer s'il existe un rapport entre l'abondance relative des juvéniles émigrants et les captures d'adultes sur les fonds de pêche commerciale des Tortugas.

De janvier 1963 à juin 1965, on a estimé l'abondance relative des juvéniles à partir de pêches faites au moyen d'un grand "channel net" dans le Buttonwood Canal, à Flamingo, dans le Parc national des Everglades. Le filet en question, dans lequel les crevettes viennent se prendre sous l'effet des courants de marée, a été employé dans la totalité du chenal. Des essais ultérieurs ont révélé que des filets plus maniables dits "wing nets" permettaient d'obtenir des sous-échantillons des crevettes se déplaçant dans le chenal, et par la suite tous les spécimens ont été pêchés avec ces engins.

On a utilisé comme indices de l'abondance mensuelle les prises de juvéniles effectuées aux approches de la nouvelle lune et de la pleine lune, et constaté une corrélation positive avec les captures commerciales des crevettes de petite taille.

Durant les périodes de grande abondance, lorsque la taille moyenne des sujets émigrant est petite (longueur de carapace égale ou inférieure à 11 mm), de 2 mois à 2 mois et demi s'écoulent entre le départ de l'estuaire et l'apparition dans les prises commerciales; lorsque les crevettes sont plus grandes, ce laps de temps tombe à un mois. Sur la base des taux de croissance, il semblerait que cette différence dans la durée de la migration correspond au temps que met l'animal à parvenir à une taille "pêchable" par les chaluts. Lorsqu'on tient dûment compte du décalage dans le temps, on améliore la corrélation entre l'abondance relative des formes juvéniles émigrantes et les captures de petites crevettes par unité d'effort sur les fonds des Tortugas. Sur cette base, il est possible d'établir une prévision de l'abondance accrue des crevettes de petite taille dans la pêcherie avant qu'elles ne soient disponibles pour la capture.

Sur la base des données sur les apports commerciaux, on relève un mouvement apparent sur le fonds de pêche des Tortugas. Les conclusions paraissent suffisamment sûres pour que l'on puisse prévoir jusqu'à 4 mois à l'avance l'accroissement de l'abondance des crevettes de la catégorie "41-50 par lb".

PRONOSTICO DEL EXITO DE LA PESCA COMERCIAL DE CAMARON EN LOS CALADEROS DE LAS TORTUGAS, BASADO EN LA ENUMERACION DE EMIGRANTES DESDE EL ESTUARIO DEL PARQUE NACIONAL DE EVERGLADES

Extracto

Desde 1962 se realizan estudios sobre las fases juveniles del camarón rosado (Penaeus duorarum Burkenroad) en el estuario del Parque Nacional de Everglades. Los objetivos de este estudio han sido aumentar los conocimientos sobre la biología y migración del camarón y determinar si existe relación entre la abundancia relativa de los juveniles emigrantes y las capturas de adultos en los caladeros de pesca comercial de las Tortugas.

Desde enero de 1963 hasta junio de 1965, se calculó la abundancia relativa mensual de juveniles basándose en las capturas efectuadas en el canal Buttonwood, en Flamingo, en el Parque Nacional de Everglades, empleando una gran "red de canal". Se pescó a lo largo de todo el canal con este arte, que aprovechaba las corrientes producidas por las mareas, para recoger muestras. Los experimentos posteriores demostraron que con "redes de ala" podían recogerse satisfactoriamente submuestras del camarón del canal, por lo qué, más tarde, todas las muestras se recogieron con este arte.

Las capturas de formas juveniles, realizadas al aproximarse los períodos de luna nueva y luna llena, se emplean como índices de la abundancia mensual. Estos indican una correlación positiva con los desembarques comerciales del camarón de talla más pequeña.

En los períodos de gran abundancia, cuando la talla media de los emigrantes es pequeña (longitud del caparazón: 11 mm, o menos), existe un retraso de dos meses a dos meses y medio desde que abandonan el estuario hasta que aparecen en las capturas comerciales. En períodos de gran abundancia, cuando los camarones son mayores, el retraso entre la captura realizada en el estuario y la captura comercial se reduce a un mes. Los índices de crecimiento indican que las diferencias en las épocas de emigración se deben al retraso en la aparición de camarón de tamaño suficiente para su captura con las redes. Cuando se emplea un intervalo de tiempo apropiado, mejora la correlación entre la abundancia relativa de juveniles emigrantes y la captura de camarón pequeño por unidad de esfuerzo en los caladeros de las Tortugas. Basándose en esta correlación se puede pronosticar la mayor abundancia de camarón pequeño en los caladeros antes de que la pesquería pueda aprovecharlo.

Valiéndose de los datos de los desembarques comerciales, puede observarse un movimiento aparente a través de las Tortugas. Se puede hacer un pronóstico bastante seguro con una anticipación de hasta 4 meses acerca de la mayor abundancia de camarones de talla correspondiente a 41-50 ejemplares por libra.

1 INTRODUCTION

Studies have been underway since late 1962 on the juvenile stages of the pink shrimp (Penaeus duorarum Burkenroad), in the Everglades National Park estuary. The principal objective has been to increase knowledge of the biology and migration of the shrimp, primarily in terms of changes in seasonal abundance and size distribution. A secondary objective has been to determine if a relationship exists between the relative abundance of emigrating juveniles and the catches of adults on the Tortugas commercial fishing grounds. It is this latter phase of the program which is discussed here. This work has been supported by the U.S. Department of the Interior, Bureau of Commercial Fisheries.

Fluctuations in availability of shrimp are of considerable importance to the industry. If they can be explained in relation to fluctuations in environmental conditions, or detected through changes in availability of younger stages, prediction of fishing success may be possible. More efficient operation of the commercial industry would result from this.

The pink shrimp is believed to be an annual crop. The success of a fishery which exploits annual crops is influenced to a large degree by short-term environmental changes. Furthermore, without the dampening effects of more than one year class, the fluctuations may be of greater magnitude. Hence, the problem of prediction of such species is difficult.

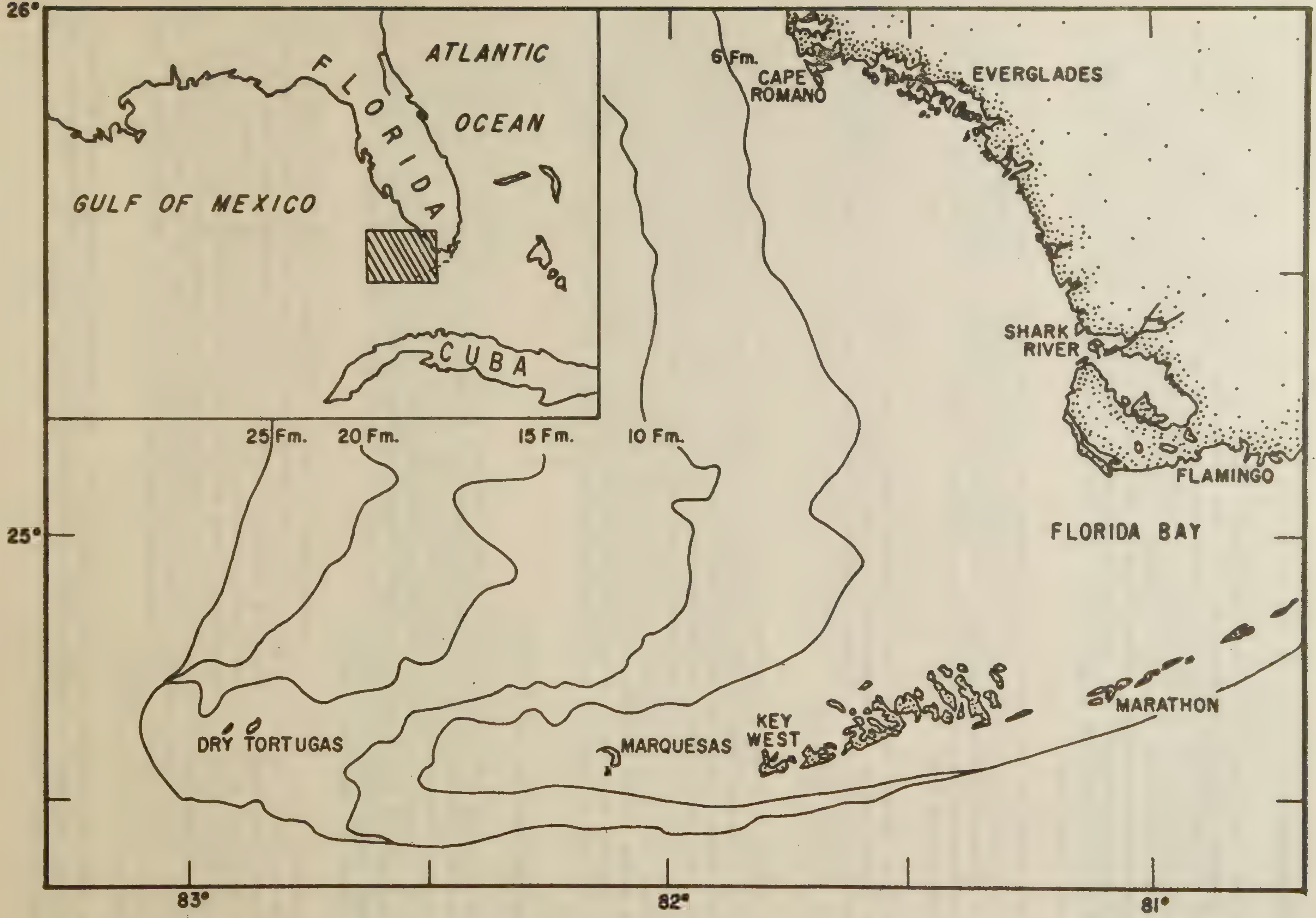
The Tortugas fishing grounds are south and west of the southern tip of Florida (Fig. 1.). Fishing takes place on adult populations in water about 15 to 20 fm (27.4 to 36.6 m) deep. Spawning takes place on the fishing grounds and the young hatch and move into shallower water, including the estuaries at the southern tip of the Florida peninsula. They enter the Whitewater-Coot Bay estuary as postlarvae in the 6-7 rostral spine stage (about 10 mm total length, i.e. tip of rostrum to tip of telson) at night on flooding tides (Tabb, Dubrow and Jones, 1962). After a period in the estuary ranging from two months or less to about six months (Costello and Allen, 1966), the juvenile shrimp move out of the estuary on ebbing tides to return to the offshore grounds to spawn.

2 SAMPLING METHODS AND LOCATION

From January 1963 through June 1965 the relative monthly abundance of juveniles was estimated from catches in Buttonwood Canal at Flamingo in Everglades National Park using a large "channel net" (Yokel, Roessler and Iversen, 1967). The entire canal was fished by this net, which relied on tidal currents to collect samples. This gear took advantage of the behavior of the juvenile shrimp in moving out of the estuary with the ebbing tide. The net caught virtually all shrimp longer than about 8.0 mm carapace length (about 38 mm total length).

Subsequently, a series of experiments in early 1965 showed that "wing nets" could subsample reliably the shrimp moving in the canal, and the use of the cumbersome channel net was discontinued. The wing nets are made of 1.9 cm stretched mesh webbing, the same as that used in the channel net, and are 5.18 m long from mouth to codend. The webbing is attached to a rectangular frame made of 2.54 cm diameter galvanized pipe. The mouth of each net is 1.8 m by 1.07 m. The effective fishing area of the net is 1.8 m along the surface and 0.9 m deep, since the upper 15.2 cm of the net remains out of the water. The nets taper to codends about 0.46 m in diameter and are fished from both sides of a 5.5 m skiff.

For both the channel net and the wing nets, the standard sampling interval was 30 min. Records of water velocity, depth, temperature and salinity, air temperature, wind direction and velocity, and cloud cover were kept for each sample.


26°
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ATLANTIC
OCEAN
FLORIDA
GULF OF MEXICO
CUBA
6 Fm.
10 Fm.
15 Fm.
20 Fm.
25 Fm.
CAPE ROMANO
EVERGLADES
SHARK RIVER
FLAMINGO
FLORIDA BAY
MARATHON
KEY WEST
MARQUESAS
DRY TORTUGAS

Fig. 1 Spawning and nursery area of the Tortugas population of pink shrimp (Penaeus duorarum).

3 RELATIVE ABUNDANCE OF EMIGRATING JUVENILE SHRIMP

To compare the catches of shrimp in Buttonwood Canal with commercial catches of shrimp on the Tortugas grounds, it is necessary to establish a standard measure of abundance of shrimp migrating out of Buttonwood Canal. A series of such standard measures of relative abundance can be compared with the catches of commercial pink shrimp. If a constant relationship can be shown to exist between the indices of abundance of migrating juveniles at Flamingo and catches on the commercial fishing grounds some time later, it is then possible to establish a system for the prediction of commercial catches from catches of juveniles.

To learn what factors are important in establishing a monthly index of abundance, monthly sampling times were selected randomly, and about equal numbers of flood and ebb tides were sampled. Some of the important factors affecting the numbers of shrimp were (1) light, (2) the direction of the tide, (3) the stage of the tide, and (4) moon phase.

Juvenile pink shrimp migrate almost exclusively at night, and virtually no shrimp were collected in daylight samples. A series of fourteen pairs of ebb-flood tides in which the two tides were fished on the same or adjacent nights during 1963 showed that relative abundance averaged over twenty times higher on ebb tides than on flood tides. Night samples collected at velocities in excess of 0.07 mi/h (0.31 m/sec) provided a more reliable index of abundance than samples taken at lower velocities.

Differences in relative abundance were also noted within months. The numbers of shrimp moving out of the estuary were higher in periods of new and full moons than during other times of the month. In 1963, 118 samples were collected on or near the time of new or full moons, and 130 samples about the time of the first or third quarter moons. The average 30 min catch during the new and full moon periods was 1,100 shrimp, compared to an average of 600 shrimp per 30 min on quarter moons. During seasons of low relative abundance the samples taken on quarter moons were about the same size as new and full moon catches, but in times of high abundance, new and full moon catches were larger than quarter-moon samples and showed a closer relationship to the commercial landings. With these data the monthly sampling schedule was adjusted to maximize the catch and provide the best prediction index.

A special study in 1964-65 showed that a consistently high proportion of the juvenile shrimp (average 78 percent on new moons; 91 percent on full moons) migrated in the upper 50 cm of water during the new and full moons (Beardsley, 1967). This suggests that on new and full moons the number of shrimp caught by both the channel net and the wing nets is strongly influenced by the volume of surface water (the upper meter) filtered and that the measure of relative abundance should be the number of shrimp per unit volume of surface water filtered. However, the volume filtered in the surface layer is essentially a function of velocity and it is possible to use velocity instead of water volume as an index.

Water velocity was measured at a depth of 50 cm with a Gurley current meter (Yokel, Roessler and Iversen, 1967) operated continuously during each 30 min sampling period. The number of revolutions of the meter during this period was used as the measure of water passing through the gear. The relative abundance estimate employed is a ratio of the number of shrimp caught divided by the total number of revolutions. Thus, the index of relative abundance for a particular month is the number of shrimp caught per revolution of the current meter on ebb tides at night during the periods of new and full moons.

4 RELATIVE ABUNDANCE OF SHRIMP ON THE TORTUGAS GROUNDS

An index of abundance of shrimp on the Tortugas grounds has also been established. This is the pounds per boat day of the smallest commercial size group (68 shrimp tails to the pound (150/kg), and smaller) caught in 15 fm (27.4 m) or less. These small shrimp are caught relatively close to the nursery areas and their numbers should show the most direct relationship with the numbers of emigrating juveniles. The data used to calculate this index are published by the United States Fish and Wildlife Service, Bureau of Commercial Fisheries in a monthly bulletin entitled "Gulf Coast Shrimp Data".

5 RESULTS

For 1963 through 1965, the relative monthly abundance of shrimp emigrating from Buttonwood Canal is shown in Fig. 2. The mean size of shrimp, expressed in mm carapace length, for each mode of abundance appears in brackets inside the mode. The means have been calculated by weighting the average size for each month according to the abundance in that month.

After the shrimp leave the nursery area, they travel 50 to 80 mi (80 to 130 km) to the Tortugas fishing grounds. Thus, a time lag exists between the departure of the shrimp from Buttonwood Canal and their first appearance in the fishery. In our first attempt to correlate catches of emigrating juveniles with catches by commercial trawlers, this lag is disregarded, and the relationship is shown in Fig. 3. The solid line represents the number of pounds of "68-count-and-over" shrimp caught per boat day in 1963 through 1965. The broken line is the number of shrimp per revolution of the current meter in Buttonwood Canal. Breaks in the line in June and November 1963 represent months when samples were not taken during new or full moons.

In both 1963 and 1964, there were two seasonal peaks of commercial catches on the Tortugas grounds, whereas in 1965 there was a single peak. The data from Buttonwood Canal show similar peaks, but they occur slightly before those in the commercial catch. Estimates of growth rates and data from marked shrimp give evidence that these are the same groups of shrimp. On a yearly basis, emigrating shrimp range in size from 2 to 45 mm in carapace length, with a mean size of about 14 mm.

Kutkuhn (1966) gives equations for the conversion of carapace length measurements to total length for male and female shrimp. From these data a reasonably accurate size dependent conversion value (sexes combined) may be calculated. For shrimp with a carapace length of 30 mm or smaller total length may be estimated by multiplying carapace length by a constant of 4.6; for larger shrimp the constant is 4.4.

Direct information on the growth rates of juvenile shrimp within the estuary and during migration is not available and therefore it is necessary to use indirect methods to obtain an estimate of these rates. From data provided by Kutkuhn (1966) it is possible to estimate the mean rate of growth of shrimp from birth until they reach a size of about 24 mm carapace length and to make a more precise estimate of their growth during the recruitment phase on the eastern edge of the grounds. Kutkuhn estimates that a shrimp of 23 to 24 mm carapace length (70 headless count) is roughly 15 weeks old, which implies an average growth rate of 6.7 mm carapace length per month from birth through the juvenile stage. Present studies underway in Everglades National Park by the authors and others on the dynamics of postlarval and juvenile shrimp suggest this is a reasonable estimate of growth in the estuary. Accelerated growth inside the estuaries for this species has been noted by Williams (1955; 1965) and for the brown shrimp (Penaeus aztecus Ives) by St. Amant, Corkum and Broom, (1963), and Kutkuhn (1966).

During the recruitment phase on the Tortugas grounds Kutkuhn (1966) states that the shrimp increase from about 19.5 mm to 29.0 mm carapace length (123 to 37 headless count, 271 to 82/kg) in 12 weeks, which is a growth rate of 3.4 mm carapace length per month. These data suggest that the most rapid growth phase occurs in the larval, postlarval and juvenile stages, which are spent largely in the estuary, and that the growth rate slows when the shrimp arrive on the fishing grounds. For the purposes of this report the growth rate during migration is taken to be at 5.0 mm carapace length per month, a value intermediate between the average early growth rate and the growth rate on the grounds during recruitment.

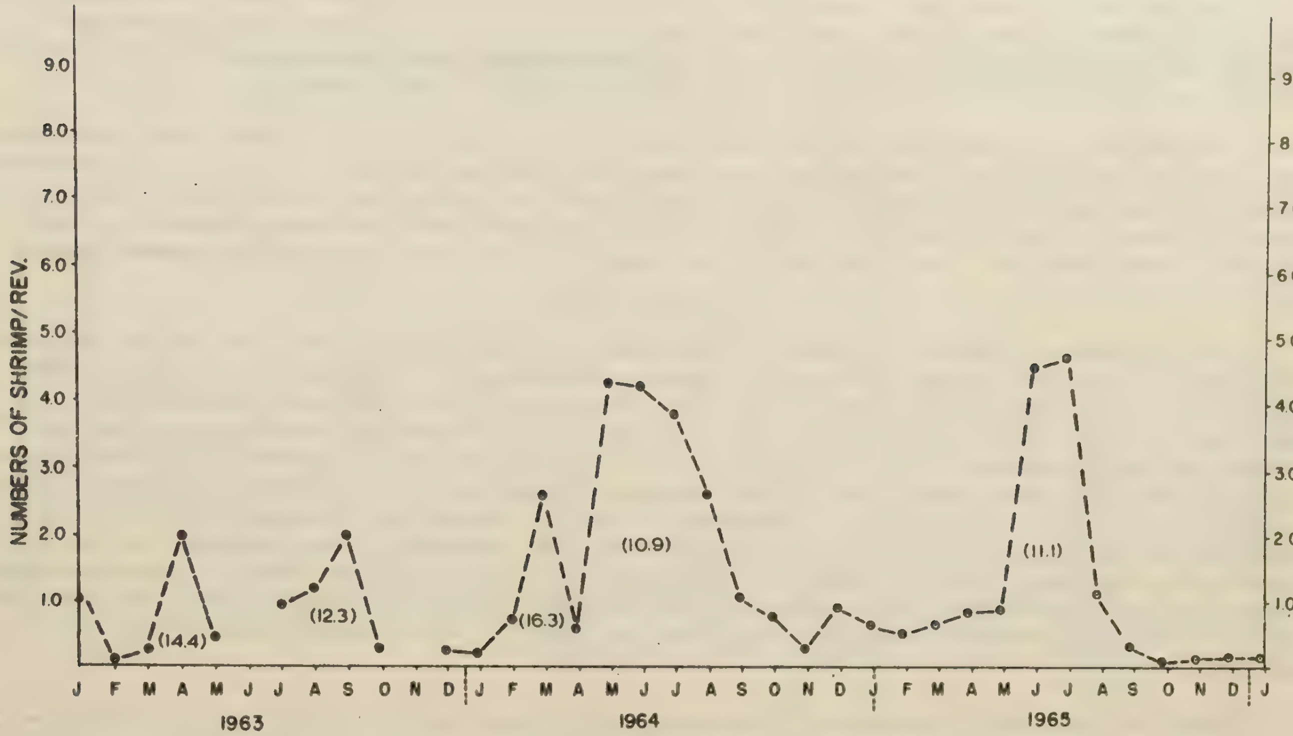

Fig. 2 Monthly indices of abundance of juvenile shrimp emigrating from the Everglades National Park nursery grounds via Buttonwood Canal at Flamingo, Florida.

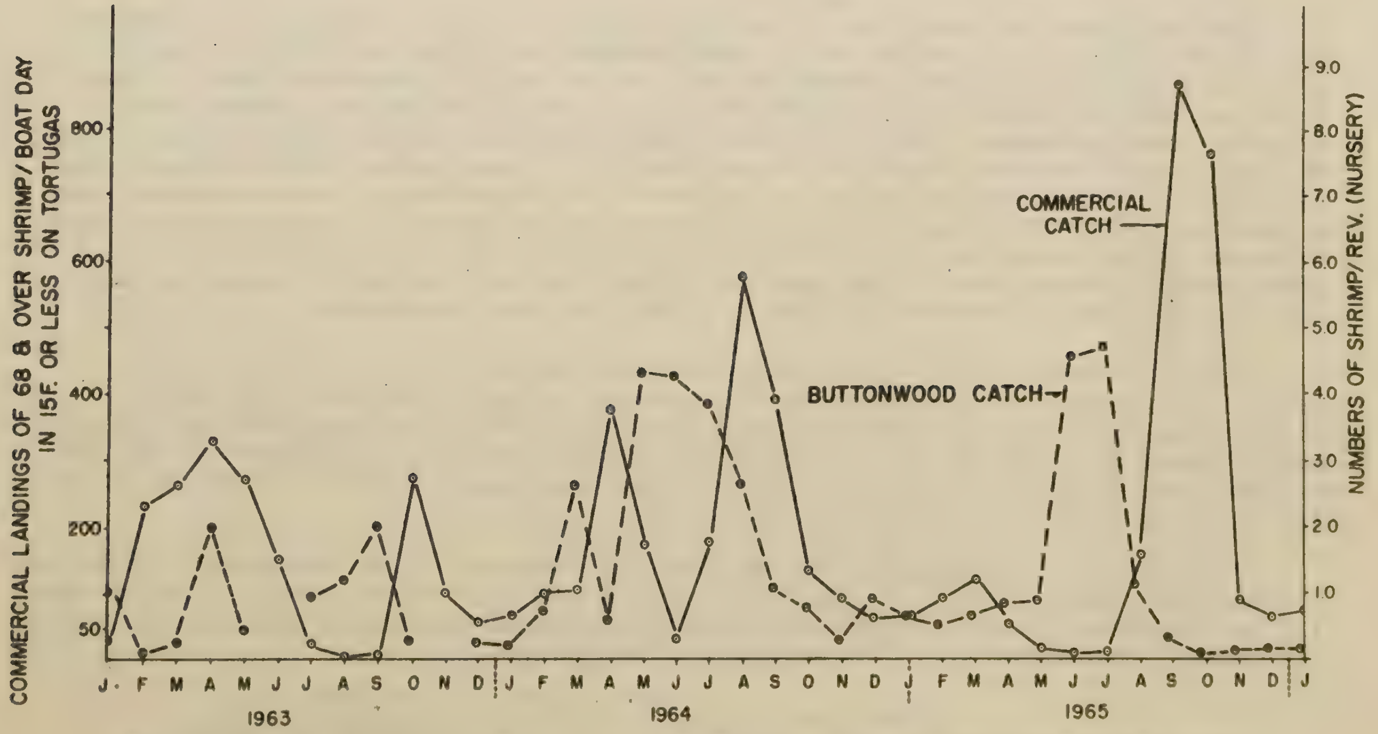

Fig. 3 Monthly indices of abundance of shrimp emigrating from the Everglades National Park nursery grounds and of commercial landings (in pounds) on the Tortugas grounds.

Shrimp in the smallest commercial category (68-count-and-over) have a carapace length of about 18 to 24 mm. Applying a growth rate of 5.0 mm carapace length per month, shrimp leaving the estuary at 14 mm (the average size on an annual basis) would be 19 mm long one month later, and would be available to the fishery.

Stained shrimp released by Costello and Allen (1966) at Shark River have been recovered on the Tortugas grounds in a minimum of 35 days. About 10 percent of the recovered shrimp were caught in 38 days or less (Costello and Allen, personal communication). Thus a "lag" of something over a month between the time shrimp caught in Buttonwood Canal and the time they are first caught on the Tortugas grounds seems reasonable.

The agreement between indices of abundance at Buttonwood Canal and on the Tortugas grounds is improved if the commercial catch is compared to the previous month's catch of juveniles in Buttonwood Canal (Fig. 4). The first three periods of abundance in Buttonwood Canal now match periods of abundance in the Tortugas landings and the mean sizes of the Buttonwood catch are such that in one month with a growth of 5.0 mm carapace length they are available to the fishery. However, the two larger peaks are still displaced by 1 to 1-$^1/_2$ months. Presumably this is caused by a delay in the arrival of the shrimp at a size large enough for the trawls to capture. This supposition is supported by the small average size of shrimp (about 11 mm carapace length) making up the catch at Buttonwood Canal during these two periods. From this small size a minimum of two months would be required for the shrimp to grow to the smallest exploitable size, and use of this increased lag time is justified.

Thus to predict an increase in the availability of small shrimp on the Tortugas grounds from the catches of juveniles leaving Buttonwood Canal, both the time of high relative abundance and the size of the individuals must be known, the latter being used to determine the extent of the lag period. Based on this relationship a forecast of availability of small shrimp on the fishing grounds can be made 1 to 2-$^1/_2$ months before they are available to the fishery.

The usefulness of these predictions of abundance is also enhanced, if there is more "lead time" (i.e., the period of time between prediction and harvest) and if the predictions include large shrimp as well as the small 68-and-over group. When plots are made of average monthly catches per boat day (reduced to a common base) by shrimp size category, a series of modes appear which represent periods when shrimp of a particular size were most available (Fig. 5). These modes first represent the smallest size group, and as the modes progress along the abscissa in successive size categories their displacement represents growth of the shrimp. Lines representing estimated growth rates have been fitted by eye through the values associated with these modes. The slopes of the lines are consistent and the growth rates implied are similar to those observed by Kutkuhn (1966) for this population.

This relationship can be used to extend the lead time of the forecasted abundance. The graph shows five periods of abundance in the 68-and-over size group. Four of these can be traced two months later to the 41 to 50 size category (90 to 110/kg). Thus if there is a two-month lag between the estuary and their appearance in the 68-and-over size group it is possible to anticipate increased abundance in the 41 to 50 size group up to four months in advance.

In addition to predicting that catches will increase in the commercial fishery at a particular time, it would be useful to predict the size of the group of shrimp entering the fishery. So far the variation around this relationship is too high to permit an accurate prediction of relative sizes of the groups.

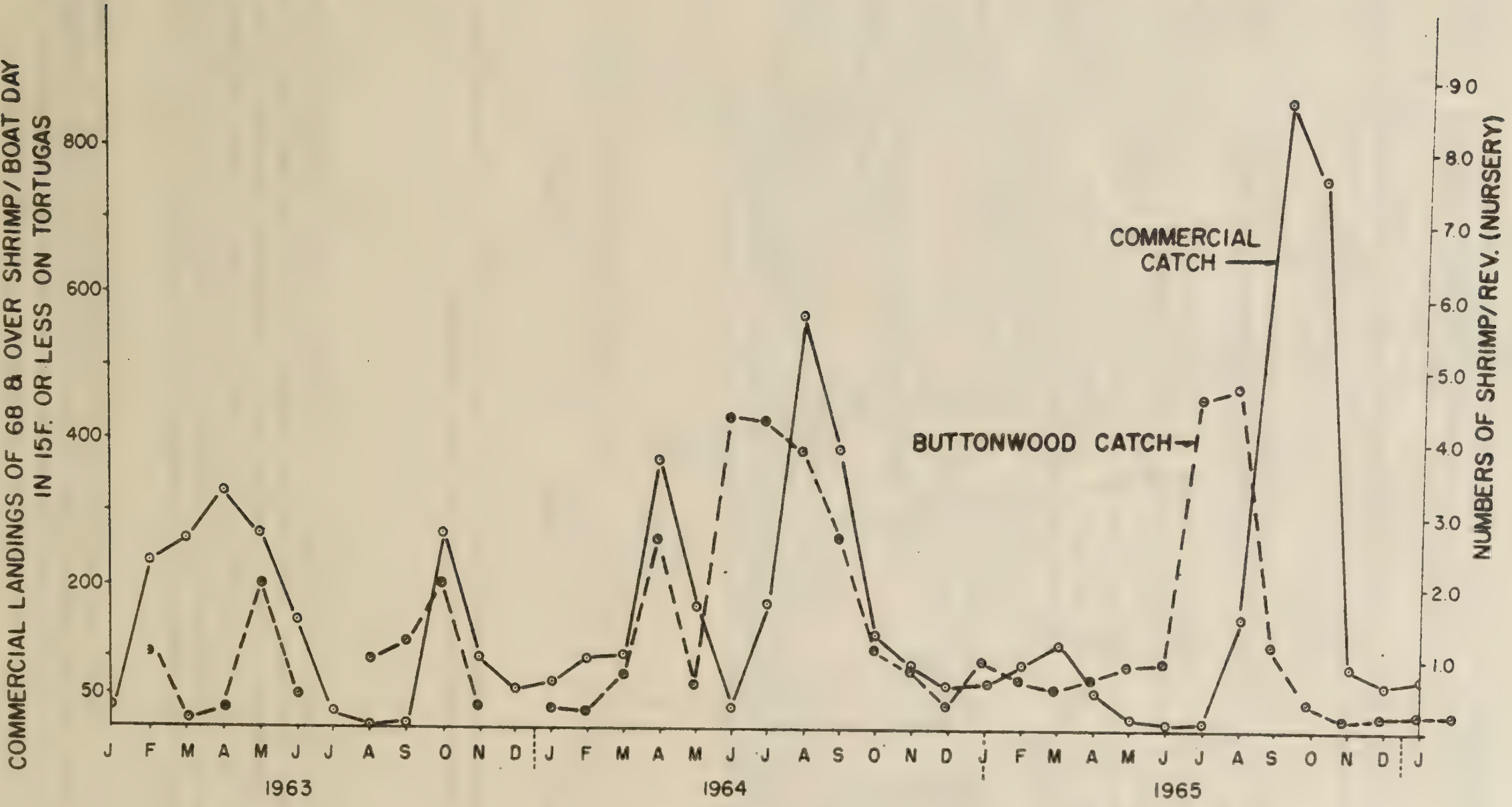

Fig. 4 Monthly indices of juvenile shrimp abundance, advanced by one month, and of commercial landings (in pounds) on the Tortugas grounds.

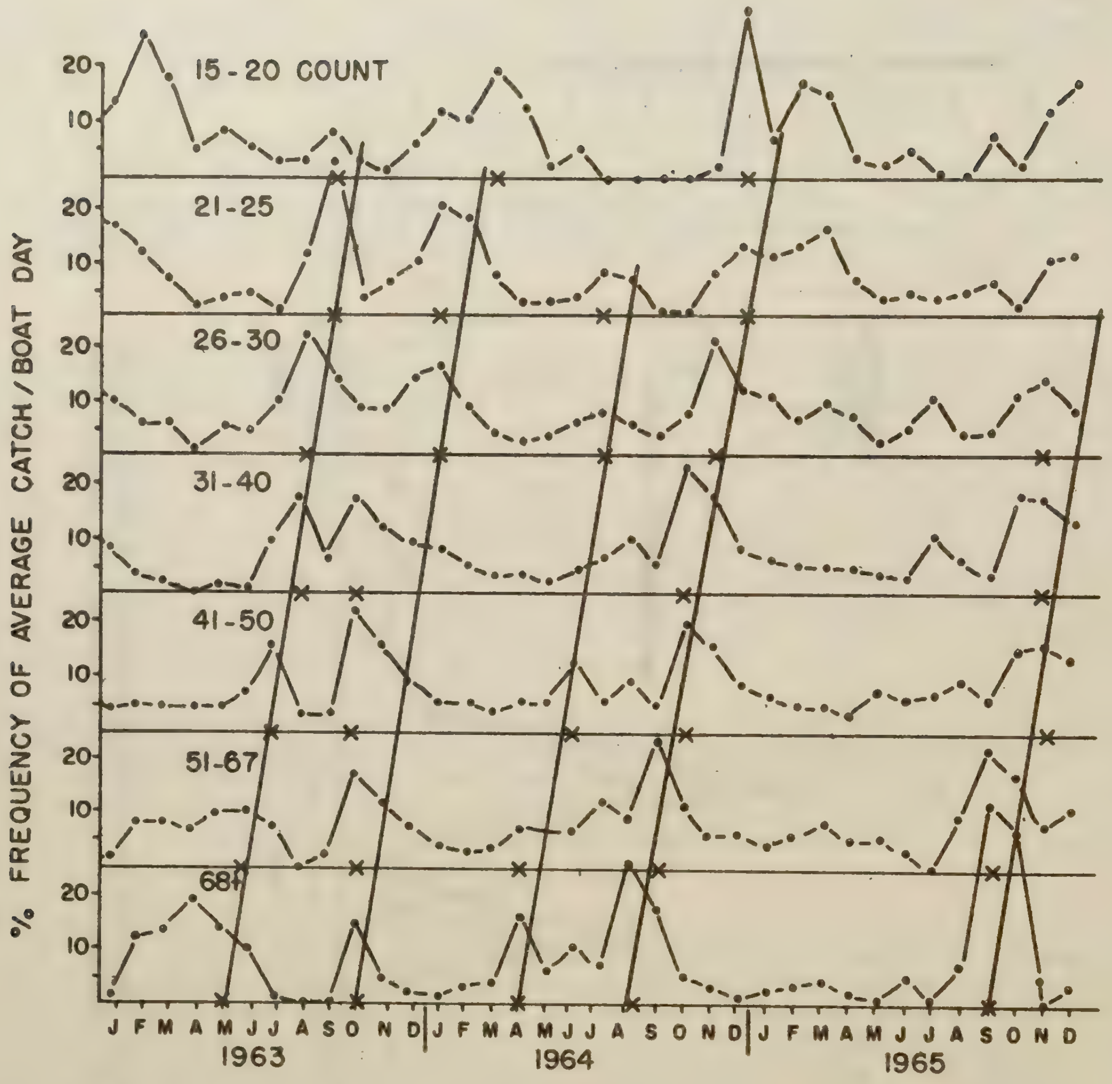

Fig. 5 Average commercial catch per unit of effort of pink shrimp by size groups on the Tortugas grounds.

6 CONCLUSION

Standard measures of relative abundance for juvenile shrimp emigrating from estuarine areas in Everglades National Park and for shrimp in the smallest commercial category have been established which permit predictions of moderate accuracy of the appearance of groups of small shrimp on the Tortugas fishing grounds. Such influxes of small commercial shrimp may be detected in progressively larger size categories with time, thus increasing the lead time of the prediction and enabling it to be applied to larger size groups.

To improve these predictions we need more precise information on the factors which control the length of stay in the estuary and on the growth rates in the estuary and during migration. Also, the size distribution of the 68-and-over commercial size category is required to determine the size at recruitment into the fishery.

It is thus possible to make a qualitative prediction of shrimp abundance on the Tortugas grounds based on estimates of pre-recruit abundance. With refinements a quantitative prediction may be possible.

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A COMPUTER PROGRAM FOR HANDLING DATA ON THE ABUNDANCE OF SHRIMP AND ASSOCIATED ANIMALS [1]

by

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Abstract

A computer program is presented to summarize ecological data and to estimate the sample size necessary for establishing an index of abundance from replicate samples. The dimensions of these programs are 10 replicates and 999 individuals per sample. The writing of summary tables is done with an autocoder program compatible with a 1401 computer. Calculations of the sample variance, coefficient of variation and number of replicates necessary to estimate relative abundance are made with a Fortran II program which is compatible with most computer systems.

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PROGRAMMATION DE CALCULATEURS POUR LE TRAITEMENT DES DONNEES SUR L'ABONDANCE DES CREVETTES ET ESPECES AFFINES

Résumé

Les auteurs présentent un programme pour calculateur électronique visant à récapituler les données écologiques et à estimer la taille de l'échantillon nécessaire pour établir un indice d'abondance à partir d'échantillonnages réitérés. Dimensions du programme : 10 réitérations et 999 individus par échantillon. Les tableaux récapitulatifs sont établis à l'aide d'un programme autocodeur compatible avec un ordinateur 1401. Le calcul de la variance de l'échantillon, du coefficient de variation et du nombre de réitérations nécessaires pour l'estimation de l'abondance relative est fait au moyen d'un programme Fortran II, compatible avec la plupart des systèmes de calculateurs.

PROGRAMA CON CALCULADORAS PARA TRATAR LOS DATOS SOBRE LA ABUNDANCIA DE CAMARONES Y ANIMALES ASOCIADOS

Extracto

Se expone un programa con calculadoras para resumir datos ecológicos y determinar el tamaño de la muestra necesario para poder establecer un índice de la abundancia mediante muestras reiteradas. Las dimensiones de estos programas son de 10 reiteraciones y 999 ejemplares por muestra. La elaboración de los cuadros resumidos se efectúa con un programa autocodificador compatible con una calculadora 1401. Los cálculos de la variancia de la muestra, coeficiente de variación y número de reiteraciones precisas para estimar la abundancia relativa se realizan con un programa Fortran II que es compatible con casi todos los sistemas de calculadoras.

1 INTRODUCTION

In September 1963, the Division of Fishery Sciences of the Institute of Marine Sciences, University of Miami, began a quantitative ecological study of the estuarine regions of Everglades National Park. Particular emphasis was placed on assessing the effects of fresh water supply upon the biota, of which the pink shrimp, Penaeus duorarum Burkenroad is a dominant member. This study was supported by U.S. Public Health Service, Division of Water Supply and Pollution Control.

The principal aims of the investigation were to relate seasonal variations at the species and population levels to changes in salinity, temperature and substrate type. Other parameters were also considered and provisions were made in establishing the computer program to include eight additional habitat variables in subsequent computer analyses.

Tagging of juvenile pink shrimp P. duorarum in the Buttonwood Canal and Shark River areas (Tabb, Dubrow and Jones, 1962; Costello and Allen, 1966) has demonstrated a link between this population and the shrimp caught in the Tortugas fishery (Fig. 1). Water in the study area undergoes seasonal salinity fluctuations between 1 and 70°/oo, providing an opportunity to study changes in abundance and size composition of the shrimp and other populations in response to salinity changes.

2 SAMPLING EQUIPMENT AND METHODS

The sampling method and the statistical treatment of the data are described in detail by Tabb and Thomas (MS) and are summarized briefly here. The first year of the 3-yr study was devoted to the development of a quantitative method of sampling. Potential sources of variation such as towing speed, towing direction and substrate type were evaluated. Replicate samples were taken from a permanent station of 100 yd^2 (91.4m^2), near Murray Key (Fig. 1). A fixed station was chosen rather than operating in a larger area on a random sampling basis because the study of effects of environmental fluctuations on animal abundance was the major consideration (Greig-Smith, 1964). The substrate of the sampling area consisted of calcium carbonate mud covered by a dense growth of turtle grass, Thallassia testudinum. The sampling gear was a 2-m otter trawl (modified shrimp "try net") from Standard Marine Supply, Key West, Florida. A $^1/_2$-in stretched mesh liner was inserted in the codend of the net.

Samples were collected once every two weeks for a period of one year. Ten drags per trip were chosen because that was the greatest number of samples that could be sorted conveniently during the two-week period between trips.

The data were analyzed to determine how many samples were required to detect changes in the population mean abundance. Estimates of the required number of replicates (N) were made using 10 months' data. The maximum allowable error was ±50 percent of the population mean. This error was tolerated to allow a large number of species to serve as possible environmental indicators.

The number of replicates (N) needed to obtain estimates which are within ±50 percent of the mean were obtained from the formula

$$N = \frac{4\ S^2}{(.5\bar{x})^2} \quad \text{(Snedecor, 1962: 501)}$$

3 DATA PROCESSING

The long series of replicated observations collected during this study required mechanical data handling. The system described below is compatible with an IBM 1401 computer.

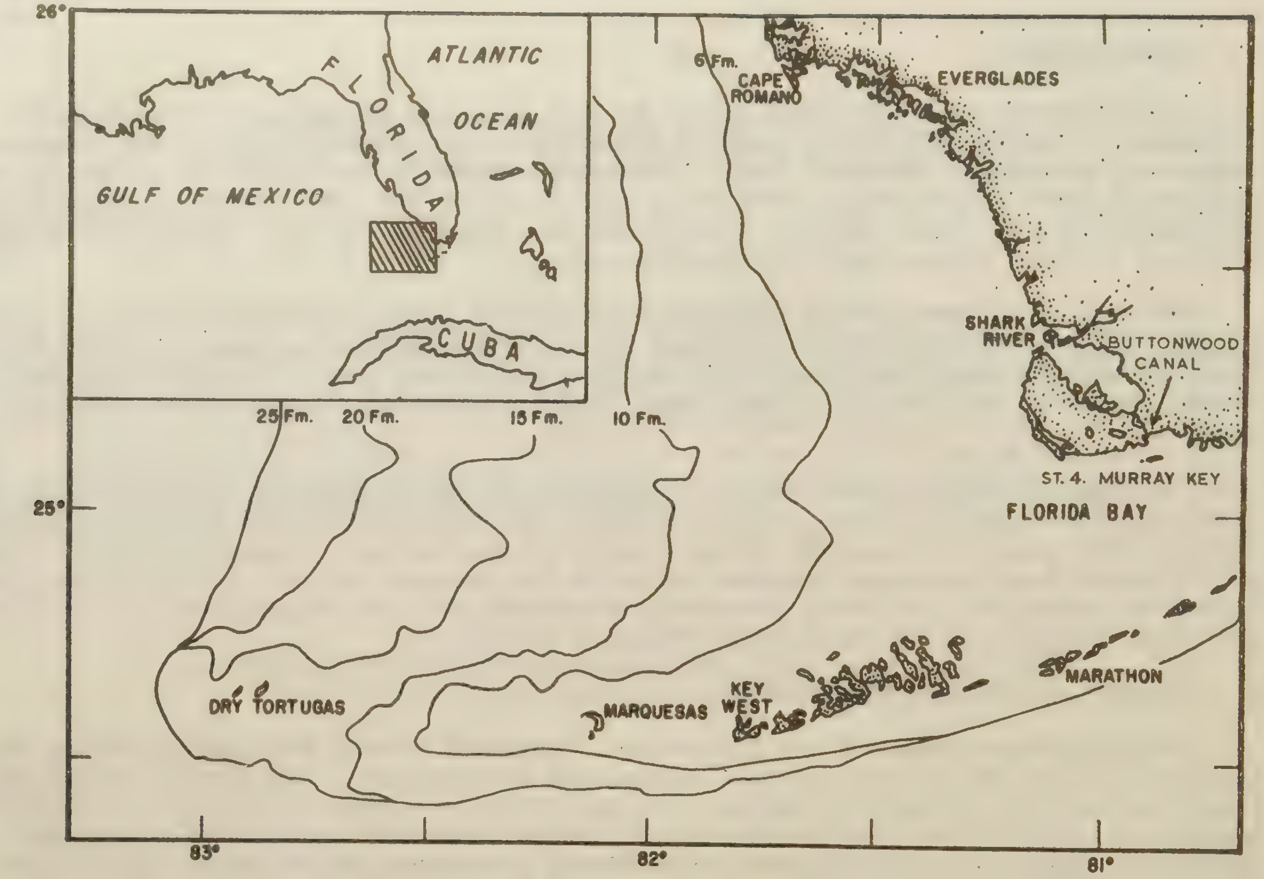

26°
25°
83°
82°
81°
ATLANTIC
OCEAN
FLORIDA
GULF OF MEXICO
CUBA
6 Fm.
CAPE ROMANO
EVERGLADES
SHARK RIVER
BUTTONWOOD CANAL
ST. 4. MURRAY KEY
FLORIDA BAY
25 Fm.
20 Fm.
15 Fm.
10 Fm.
DRY TORTUGAS
MARQUESAS
KEY WEST
MARATHON

Fig. 1 The location of the sampling site (Station 4) in relation to the estuarine areas of Everglades National Park and the Tortugas fishing grounds.

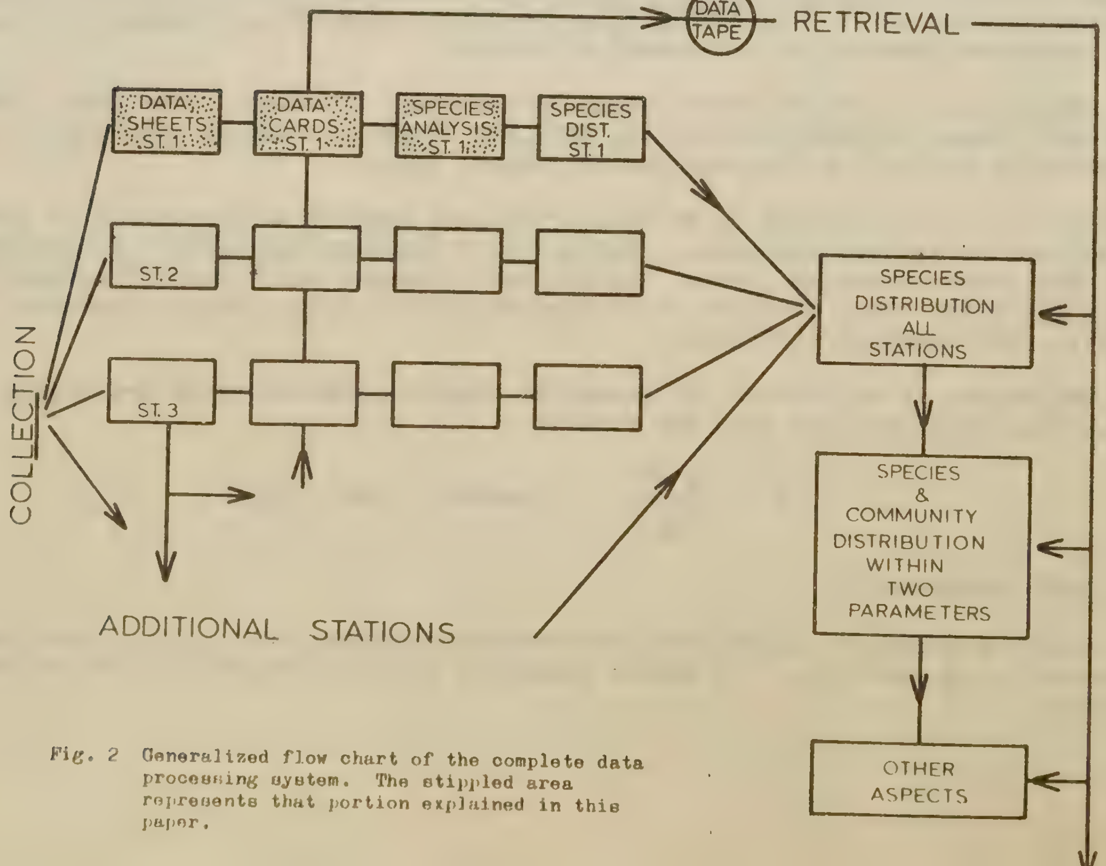

DATA TAPE
RETRIEVAL
DATA SHEETS ST. 1
DATA CARDS ST. 1
SPECIES ANALYSIS ST. 1
SPECIES DIST. ST. 1
ST. 2
ST. 3
COLLECTION
ADDITIONAL STATIONS
SPECIES DISTRIBUTION ALL STATIONS
SPECIES & COMMUNITY DISTRIBUTION WITHIN TWO PARAMETERS
OTHER ASPECTS

Fig. 2 Generalized flow chart of the complete data processing system. The stippled area represents that portion explained in this paper.

A generalized flow chart of the data storage and retrieval system developed for this study appears in Fig. 2. The stipled portion of this figure represents the part of the system used to analyze the shrimp data presented in this paper. However, whether utilizing the whole or only part of this system, the methods of data acquisition, recording, and punched card formats remain the same. Standardization of these initial stages does not result in the loss of any flexibility, and the system remains open-ended at all times. No compensatory measures are needed to offset seasonal changes in species composition at the station level, and the number of stations may be increased or decreased at any time.

4 DATA RECORDING

Careful consideration of the purposes of the experiment will make it easier to organize the data on the card. In the same way, field data sheets can be designed which minimize the work in transferring data. Where the initial goals of the experiment are less clear, more complicated data sorting procedures may be required.

The field data sheet designed for this program is shown in Fig. 3. The upper portion of this form, under the sub-heading "Samples", provides enough space to record the data of up to ten replicate samples. Space is provided to include the measurements of 50 individual animals from each of the 10 samples, while the total number of individuals per sample is recorded in the appropriate space under the sub-heading "Punch". In this section, a "minus one" was included if samples were not taken or were lost. This provides the computer with the necessary information to adjust for a change of sample size when making other calculations. The sample weight and the average size, minimum size and maximum size of individuals can also be filled in by the person sorting the sample. The rest of the information on this line is explained in detail in the appendix section on data card format.

On completion, these data sheets can be given directly to a key punch operator and data cards cut from them. One data sheet per species per trip is required.

5 PUNCHED CARD FORMAT

The input for the program consists of punched cards. Three specific card types are used to make up the library file. These are:

Name card (scientific name, code number);

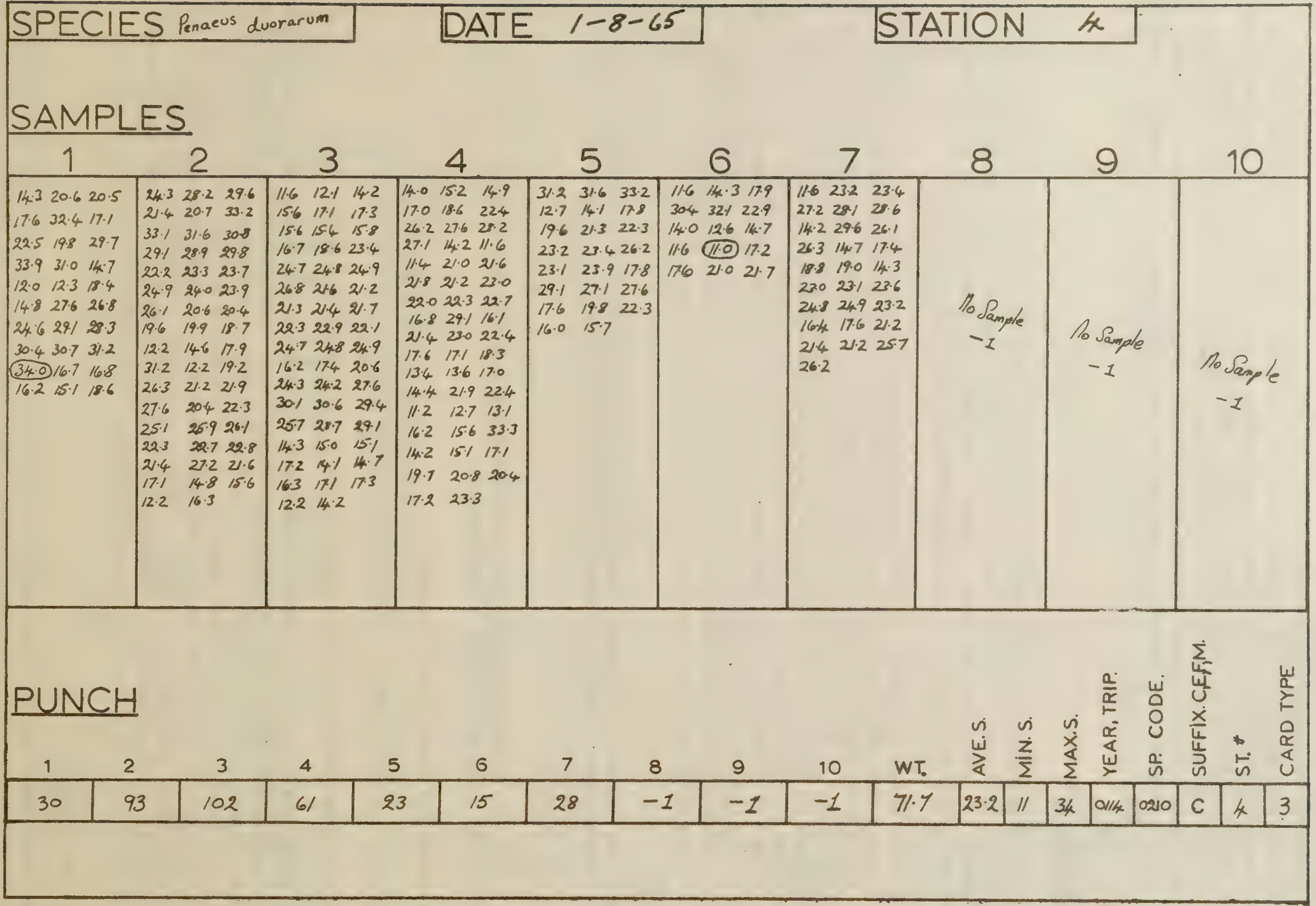
Data card (how many, what, where, when, code number); and

Parameter card (environmental conditions, where, when, code number).

Although only one species is being considered in this paper, complete cross referencing is possible for any number of species and stations by the use of appropriate code numbers on each card. The data card is the control (e.g., if no data exist for a certain species on a certain trip, then there is no utilization of the name or parameter cards). Such a coded cross reference system allows for a greater condensation of information, either in core storage or on tape. This, in turn, provides an economy of time and effort by avoiding unnecessary duplication. Specific details of the card format for each card type are shown in the Appendix Tables I, II and III.

5.1 Sorting routine

All input data must be in some logical order acceptable to the program being used. With this program the sequence is as follows. The three kinds of cards listed earlier are sorted by ascending species code number, followed by an ascending order of each trip, each year and each station separately. In order to make this separation of the data when using an IBM 082 card sorting machine, the order of sorting by card columns must be 70, 69, 68, 67, 75, 74, 73, 72, 76, 78, 80.



SPECIES *Penaeus duorarum* DATE 1-8-65 STATION 4

SAMPLES

1	2	3	4	5	6	7	8	9	10
14.3 20.6 20.5	24.3 28.2 29.6	11.6 12.1 14.2	14.0 15.2 14.9	31.2 31.6 33.2	11.6 14.3 17.9	11.6 23.2 23.4	No Sample −1	No Sample −1	No Sample −1
17.6 32.4 17.1	21.4 20.7 33.2	15.6 17.1 17.3	17.0 18.6 22.4	12.7 14.1 17.8	30.4 32.1 22.9	27.2 28.1 28.6			
22.5 19.8 29.7	33.1 31.6 30.8	15.6 15.4 15.8	26.2 27.6 28.2	19.6 21.3 22.3	14.0 12.6 14.7	14.2 29.6 26.1			
33.9 31.0 14.7	29.1 28.9 29.8	16.7 18.6 23.4	27.1 14.2 11.6	23.2 23.4 26.2	11.6 11.0 17.2	26.3 14.7 17.4			
12.0 12.3 18.4	22.2 23.3 23.7	24.7 24.8 24.9	11.4 21.0 21.6	23.1 23.9 17.8	17.6 21.0 21.7	18.8 19.0 14.3			
14.8 27.6 26.8	24.9 24.0 23.9	26.8 21.6 21.2	21.8 21.2 23.0	29.1 27.1 27.6		23.0 23.1 23.6			
24.6 29.1 28.3	26.1 20.6 20.4	21.3 21.4 21.7	22.0 22.3 22.7	17.6 19.8 22.3		24.8 24.9 23.2			
30.4 30.7 31.2	19.6 19.9 18.7	22.3 22.9 22.1	16.8 29.1 16.1	16.0 15.7		16.4 17.6 21.2			
34.0 16.7 16.8	12.2 14.6 17.9	24.7 24.8 24.9	21.4 23.0 22.4			21.4 21.2 25.7			
16.2 15.1 18.6	31.2 12.2 19.2	16.2 17.4 20.6	17.6 17.1 18.3			26.2			
	26.3 21.2 21.9	24.3 24.2 27.6	13.4 13.6 17.0						
	27.6 20.4 22.3	30.1 30.6 29.4	14.4 21.9 22.4						
	25.1 25.9 26.1	25.7 28.7 29.1	11.2 12.7 13.1						
	22.3 22.7 22.8	14.3 15.0 15.1	16.2 15.6 33.3						
	21.4 27.2 21.6	17.2 14.1 14.7	14.2 15.1 17.1						
	17.1 14.8 15.6	16.3 17.1 17.3	19.7 20.8 20.4						
	12.2 16.3	12.2 14.2	17.2 23.3						

PUNCH

1	2	3	4	5	6	7	8	9	10	WT.	AVE.S.	MIN.S.	MAX.S.	YEAR, TRIP.	SP. CODE.	SUFFIX.C.E.F.M.	ST.#	CARD TYPE
30	93	102	61	23	15	28	−1	−1	−1	71.7	23.2	11	34	0114	0210	C	4	3

Fig. 3 The field data sheet utilized in this study. Sizes of individual animals are recorded for each sample under the heading Samples. The two circled numbers are the maximum and minimum lengths. Information recorded under the heading Punch is the required data card format and includes the total number caught per sample.

6 THE COMPUTER PROGRAM

The program required to carry out the analysis represented by the stippled area in Fig. 2 is a three-phase operation. A summary of each phase is given in Table I.

A program to operate phase 1 has not been given in this paper since this step can be accomplished by using a standard utility program (i.e., cards to tape). The source programs for phases 2 and 3 are appended (Appendix Tables IV and V). The final printed output from phase 3 of this program is given in Table II. The layout of this table is identical to the actual computer printout.

TABLE I

Summary of the input, operation and output steps required to produce the printed output of Table II

Phase	Input	Operation	Output
1	Cards – Data Parameter Name	Cards to tape Utility program not listed	Tape 1 Data Tape 2 Parameters Tape 3 Names
2	Tape 1 of output phase 1	Calculations Fortram program (Appendix Table IV)	Tape 4
3	Tape 4 Tape 2 Tape 3	Construction of arrays Autocoder program (Appendix Table V)	Printed (Listing Table II)

7 SUMMARY

The program described in this paper provides a complete and condensed presentation by species by station of data collected in a large scale ecological investigation. Ten environmental parameters can be included.

This program is open-ended, permitting changes in the number of species or stations. It can be applied to any set of replicate samples providing these do not exceed ten. If the number of individuals per sample exceeds the maximum field size of 999, a suitable scale can be applied to the data. However, other card field sizes (i.e. parameters, codes, etc.) must be adhered to (see Appendix Tables I, II and III).

The calculation of the number of replicates (N), the sample variance, the standard deviation and the coefficient of variation provide the basic statistics. The layout of the printed output in Table II is compatible with the input requirements of several multi-variate statistical programs (Clyde, Cramer and Sherin, 1966) if a more sophisticated analysis of the data is required.

The use of a computer program like the one described here speeds up the analysis of data in suitable cases. But considerable work is required to reorganize data into the necessary formats unless proper field data sheets are designed.

TABLE II

Computer printout of the first ten months data, consisting of 20 trips with 10 replicate samples per trip. * Data columns left to right: Date, salinity in parts per thousand, Temperature in ^{o}C, time of day, wind direction and velocity, vegetation weight, tunicate weight, sponge weight, precipitation between trips, evaporation between trips, species weight in grams, mean length in millimeters, minimum length in millimeters, maximum length in millimeters, total number of shrimp, mean number of shrimp, sample variance, standard deviation, coefficient of variation, detectable error ± 50% mean squared x two, estimated number of replicates (N), station number.

Yearly Analysis

Decapoda (Penaeidae) Penaeus duorarum

0210C 4

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	Parameters												Variables								
Date	Sal.	Temp	Time	Wind	VC.W.T.	T.WT.	S.WT.	Prec.	Evap.	WT.	Size	Min	Max	Sum	Mean	Var.	Dev.	C.V.	D.F.	N	S
12 Feb 64	33.9	16.5	1430	NE 5.4	12,984	1,566		0.64	2.43	232.1	12.3	9	15	4	0.4	0.5	0.7	1.7	0.1	24.4	4
10 Mar 64	35.4	26.0	1255	S 7.8	23,789			0.02	2.51	459.3	13.4	8	20	85	8.5	30.1	5.5	0.6	36.1	3.3	4
24 Mar 64	35.6	22.0	1235	SE 7.7	21,973	1,475		1.49	3.62	212.8	13.5	11	17	30	3.0	3.1	1.8	0.6	4.5	2.8	4
7 Apr 64	39.8	24.4	1355	SE 8.0	23,744	846		0000	2.85	215.4	14.6	9	19	16	1.6	3.4	1.8	1.1	1.3	10.6	4
22 Apr 64	39.8	25.4	1320	E 5.9	45,400	910		0.06	4.09	266.6	15.3	9	20	9	0.9	0.5	0.7	0.8	0.4	5.4	4
5 May 64	41.0	25.4	0955	NE 5.3	29,918	1,038		1.64	2.42	287.8	8.7	3	17	13	1.3	3.8	1.9	1.5	0.8	17.9	4
19 May 64	42.0	24.6	1007	NE 5.0	54,934	756		0.51	3.54	592.2	7.9	4	12	22	2.2	2.4	1.5	0.7	2.4	4.0	4
3 Jun 64	40.2	26.6	0938	SW 2.7	42,630	634	12.50	4.26	2.44	548.5	8.6	3	15	104	10.4	8.0	2.8	0.3	54.1	0.6	4
17 Jun 64	38.2	28.1	0932	E 3.1	14,934	518	14.50	8.04	2.50	238.5	9.6	4	36	38	3.8	5.3	2.3	0.6	7.2	2.9	4
2 Jul 64	39.3	28.2	0845	E 3.3	6,341	684		1.57	3.38	686.9	9.5	5	16	31	3.1	4.8	2.2	0.7	4.8	4.0	4
16 Jul 64	39.6	27.2	0839	SE 4.2	3,586	1,185	3.10	0.99	3.84	251.9	12.5	8	18	11	1.1	1.2	1.1	1.0	0.6	8.0	4
31 Jul 64	42.4	29.0	0730	NE 7.9	5,584	965	37.00	1.78	3.81	184.7	11.1	8	16	12	1.2	1.1	1.0	0.9	0.7	5.9	4
8 Aug 64	41.6	29.5	1630	SE 4.3	4,630	941	37.90	1.17	1.81	193.0	11.3	7	18	22	2.2	15.3	3.9	1.8	2.4	25.3	4
24 Aug 64	45.0	30.8	1412	E 3.1	3,314	800	96.80	1.07	4.24	168.6	10.1	4	20	28	2.8	3.7	1.9	0.7	3.9	3.8	4
9 Sep 64	41.6	29.9	1615	W 5.1	2,315	874	36.40	2.02	3.38	1727.3	11.7	7	21	258	25.8	50.2	7.1	0.2	332.8	0.6	4
29 Sep 64	40.3	28.5	0735	SE 4.0	2,133	436	31.70	3.99	2.21	349.2	9.0	7	11	3	0.3	0.2	0.5	1.6	0.0	20.7	4
20 Oct 64	37.2	22.5	1330	N 1.7	7,127	966	24.50	2.21	2.63	1612.2	12.6	7	23	543	54.3	475.1	21.8	0.4	1474.2	1.3	4
17 Nov 64	33.4	25.3	1330	NE 2.1	6,004	770		3.27	3.95	289.5	13.1	10	17	61	8.7	55.9	7.5	0.9	38.0	5.9	4
15 Dec 64	33.7	21.2	1130	NE 3.8	8,896	595		0.32	3.06	3461.0	14.9	6	28	858	122.6	481.0	21.9	0.2	7511.9	0.3	4
14 Jan 65	33.4	23.0	1230	SE 1.8	7,593	769		0.31	4.39	458.7	15.1	10	20	43	6.1	12.1	3.5	0.6	18.9	2.6	4

8 APPENDICES

The method and origin of the coding system used in this program

The cycle and trip number, along with the species code, suffix (e.g., M. for Mollusk) and station numbers, provide necessary cross references. The cycle and trip numbers were written as 0101, 0102, 0103, etc. The first two figures in each case represent the year or cycle, and the second two, the trip number. The species codes were obtained by assigning numbers to the appropriate phylogenetic check lists, starting with 0010C, 0020C, etc. The zero between the 1 and 2 and the suffix "C" (crustaceans), was used to facilitate the insertion of species caught during the study but not included in the original check lists. Such codes would then be written as 001AC, 002AC, 003AC, etc., thus maintaining the species code numbers in phylogenetic order.

Appendix Table I

The specified format of the name card by card column.

Card color pink; one card per species per station

Card Column	Contents
1 - 70	Printed name (i.e., Order, family, genus and species)
72 - 75	Code number of species
76	Suffix Mollusk, Fish, Crustacean, Echinoderm
78	Station number 1, 2, 3 ...
80	Type of card 1 equals name

Appendix Table II

The specified format of the data card by card column.

Card color blue; one card per species for each station and trip

Card Column		Contents
1 - 3	Sample one	Ten replicate samples maximum field size 999 individuals per sample
5 - 7	" two	
9 - 11	" three	
13 - 15	" four	
17 - 19	" five	
21 - 23	" six	
25 - 27	" seven	
29 - 31	" eight	
33 - 35	" nine	
37 - 39	" ten	

continued.../

Appendix Table II (continued)

41 - 46	Species weight in grams
48 - 53	Average size in mm
55 - 57	Minimum size in mm
59 - 61	Maximum size in mm
67 - 70	Cycle and trip number
72 - 75	Code number of species
76	Suffix Mollusk, Fish, Crustacean, Echinoderm
78	Station number 1, 2, 3 ...
80	Type of card 3 equals Data

Appendix Table III

The specified format of the parameter card by card column.

Card color yellow; one card per station per trip

Card Column	Contents
1 - 2	Day of month (e.g., 12)
4 - 6	Month, (e.g., Oct.)
8 - 9	Year, (e.g., 66)
11 - 14	Salinity
16 - 19	Temperature degrees
21 - 24	Time of day (24 h clock)
26 - 31	Wind, velocity and direction during sampling
33 - 38	Vegetation weight in grams
40 - 44	Tunicate " " "
46 - 50	Sponge " " "
52 - 56	Precipitation in inches between trips
58 - 62	Evaporation in inches between trips
67 - 70	Cycle and trip number
78	Station number 1, 2, 3 ...
80	Type of card 2 equals parameter

Appendix Table IV

A listing of the fortran II program used to calculate the number of replicates (N), the sample variance, standard deviation, and the coefficient of variation. (Phase 2 Table I)

Start of sequence

```
PARAMI9I0508P  A
      DIMENSION NA(10), A(10), B(10), JA(10)
  1   REWIND 4
      REWIND 5
      READ 100, IREC
100   FORMAT(I5)
      ITEST = 0
2     READ INPUT TAPE 4, 101, NA, B
101   FORMAT(I3, 6I4, 1X, 3(I3, 1X), 10A4, 53X)
      IF(SENSE SWITCH 1) 3, 4
3     ILEFT = IREC - ITEST
      PRINT 205, ITEST, ILEFT
205   FORMAT(1H1,I5,17HRECORDS PROCESSED,5X,I5,17HRECORDS REMAINING)
4     ITEST = ITEST + 1
      DO 10 I = 1, 10
 10   JA(I) = 1
      N = 10
      NSUM = 0
      DO 20 I = 1, 10
      IF(NA(I)) 15, 18, 18
 15   N = N - 1
      NA(I) = 0
      JA(I) = 0
 18   NSUM = NSUM + NA(I)
 20   A(I) = NA(I)
      VAR = NSUM
      DTF = N
      AVG = VAR/DTF
      VAR = 0.0
      DO 30 I = 1, 10
      IF(JA(I)) 25, 30, 25
 25   X = A(I) - AVG
      VAR = VAR + X*X
 30   CONTINUE
      XN = N - 1
      VAR = VAR/XN
      DEV = VAR**0.5
      COEF = DEV/AVG
      DTF = 0.5*AVG*AVG
      REQD = 4.0*VAR/DTF
      IF(REQD - 1.0E4) 35, 34, 34
 34   REQD = 999.9
 35   WRITE OUTPUT TAPE 5, 201,
     1     B, NSUM, AVG, VAR, DEV, COEF, DTF, REQD
201   FORMAT(10A4,I4,5(F6.1),F5.1,54X)
      IF(ITEST - IREC) 2, 40, 40
 40   PRINT 202
202   FORMAT(13H1JOB FINISHED)
      PRINT 203
203   FORMAT(1H1)
      END FILE 5
      REWIND 5
      GO TC 1
      END
```

Appendix Table V

A listing of the autocoder program required to produce the printed output of Table II (summarized in Phase 3 Table I)

Start of sequence

```
        JOB   LIST    DATA
        CTL   6611
START   B     GO
        DATES
        SW    8,15
        SW    19
AGAIN   MLC   '0000',)0J002
        MLC   '00000',ITEST=5
        RWD   2
        RWD   5
ML1     RWD   3
        B     AO
        MLC   '2',UNIT=1
        B     DO
        B     ABO
        B     ACO
ML2     MLC   '3',UNIT
        B     DO
        B     CO
        C     ITEST,IREC
        BL    ML3
        BE    ML3
        MLC   '5',UNIT
        MLC   ZERO,D1+4
        MLC   ZERO,E4+4
        B     DO
        MLC   '1',D1+4
        MLC   '1',E4+4
        C     36,CODE
        BU    ML3
        C     30,TRIP=4
        BU    ML3
        B     FO
        B     ML4
ML3     MLC   HEAD29,295
        B     BO
        C     ITEST,IREC
        BL    ML4
        BE    ML4
        BSP   5
ML4     C     TRIP,TESTB
        BE    ML5
        B     ML2
ML5     C     CODE,TESTA
        BL    STOP
        BE    STOP
        B     ML1
AO      SBR   AE+3
        CC    1
        MLC   HEAD,275
        PDATE320
        B     BO
        W
        W
AE      B     0
```

(Continued)

```
ABO     SBR   ABE+3
        MLC   179,279
        MLC   176,CODE=5
        B     BO
        W
        W
        MLC   HEAD1,236
        MLC   HEAD2,298
        B     BO
        W
ABE     B     0
ACO     SBR   ACE+3
        MLC   HEAD3,206
        MLC   HEAD4,214
        MLC   HEAD5,219
        MLC   HEAD6,224
        MLC   HEAD7,230
        MLC   HEAD8,238
        MLC   HEAD9,244
        MLC   HEAD10,250
        MLC   HEAD11,256
        MLC   HEAD12,262
        MLC   HEAD13,267
        MLC   HEAD14,275
        MLC   HEAD15,280
        MLC   HEAD16,284
        MLC   HEAD17,289
        MLC   HEAD18,295
        MLC   HEAD19,302
        MLC   HEAD20,309
        MLC   HEAD21,316
        MLC   HEAD22,323
        MLC   HEAD23,328
        MLC   HEAD24,332
        B     BO
        W
ACE     B     0
BO      SBR   BE+3
        W
        CS    332
        CS
BE      B     0
CO      SBR   CE+3
        MLC   162,262
        MLC   170,TRIP
        C     201,ZERO
        BU    C1
        MLC   BK1,201
C1      C     228,ZERO
        BU    C2
        MLC   BK1,228
C2      C     233,ZERO
        BU    C3
        MLC   BK1,233
        C     234,ZERO
```

(Continued)

```
        BU    C3
        MLC   BK1,234
C3      C     240,ZERO
        BU    C4
        MLC   BK2,241
C4      C     246,ZERO
        BU    C5
        MLC   BK1,246
C5      C     252,ZERO
        BU    C6
        MLC   BK1,252
C6      C     258,ZERO
        BU    CE
        MLC   BK1,258
CE      B     0
DO      SBR   DE+3
        MLC   UNIT,D1+3
        MLC   UNIT,E3+3
        MLC   UNIT,E4+3
D1      RT    0,101
        BER   EO
DE      B     0
EO      SBR   EE+3
        MLC   '50',ATMPT=2
E1      MLC   '00',TRY=2
E2      A     '1',TRY
        C     TRY,ATMPT
        BL    EF
E3      BSP   0
E4      RT    0,101
        BER   E2
EE      B     0
EF      H
        BSS   E1,C
        B     AGAIN
FO      SBR   FE+3
        C     6,CHECK
        BE    F1
        MCS   6,269
F1      C     13,CHECK
        BE    F2
        MCS   13,276
F2      MCS   17,280
        MCS   21,284
        MLC   44,289
        MLC   50,296
        MLC   56,303
        MLC   62,310
        MLC   68,317
        MLC   74,324
        MLC   79,330
        MLC   38,332
        B     BO
        A     *-6,ITEST
FE      B     0
```

(Continued)

```
GO      SBR   GE+3
        SW    1,101
        R
        MLC   5,TESTA=5
        MLC   8,TESTB=2
        R
        MLC   5,IREC=5
        LCA   GK,81
        LCA   GK,181
        SW    41,45
        SW    51,57
        SW    63,69
        SW    38,75
GE      B     0
STOP    CC    1
        MLC   HEAD25,275
        B     BO
        W
        W
        MLC   HEAD26,275
        B     BO
        MLC   HEAD28,275
        B     BO
        CC    1
        H     AGAIN
HEAD    DCW   'YEARLY ANALYSIS'
HEAD1   DCW   'PARAMETERS'
HEAD2   DCW   'VARIABLES'
HEAD3   DCW   'DATE'
HEAD4   DCW   'SAL.'
HEAD5   DCW   'TEMP'
HEAD6   DCW   'TIME'
HEAD7   DCW   'WIND'
HEAD8   DCW   'VG.WT.'
HEAD9   DCW   'T.WT.'
HEAD10  DCW   'S.WT.'
HEAD11  DCW   'PREC.'
HEAD12  DCW   'EVAP.'
HEAD13  DCW   'WT.'
HEAD14  DCW   'SIZE'
HEAD15  DCW   'MIN'
HEAD16  DCW   'MAX'
HEAD17  DCW   'SUM'
HEAD18  DCW   'MEAN'
HEAD19  DCW   'VAR.'
HEAD20  DCW   'DEV.'
HEAD21  DCW   'C.V.'
HEAD22  DCW   'D.F.'
HEAD23  DCW   'N'
HEAD24  DCW   'S'
HEAD25  DCW   'LISTING COMPLETED'
HEAD26  DCW   'FOR ADDITIONAL LISTING'
HEAD28  DCW   'PUSH START'
HEAD29  DCW   'NONE CAUGHT THIS TRIP'
GK      DCW   ' '
BK1     DCW   ' '
ZERO    DCW   '0'
BK2     DCW   '  '
CHECK   DCW   '0000.0'
        END   START
```

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PROBLEMAS DE ESPECIACION EN AMERICA DE UN GRUPO DE PALAEMONIDAE DEL GENERO Macrobrachium

por

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Extracto

Las vertientes pacífica y atlántica de América, desde el sur de los Estados Unidos hasta el norte de Argentina y Chile, están pobladas por numerosas especies de la familia Palaemonidae (Crustacea, Decapoda). Estos crustáceos significan un interesante material para estudios faunísticos, dada su especial distribución geográfica. Migraciones, en épocas muy recientes, han dado lugar a formas y variedades, entre las cuales destacan rasgos de parentesco.

Macrobrachium olfersii es una especie ampliamente distribuida en la costa oriental de América. Especies afines se encuentran en las Antillas y norte de Sudamérica. La costa pacífica de Centroamérica y México tiene también especies que no ocultan sus afinidades con M. olfersii.

La intención de esta ponencia es tratar de encontrar hasta qué punto las especies del grupo olfersii constituyen un conjunto natural, así como establecer la distribución geográfica y las líneas de invasión de nuevos territorios, como son las cuencas hidrográficas de la vertiente pacífica.

TAXONOMIC PROBLEMS WITH A GROUP OF PALAEMONIDAE OF THE Macrobrachium GENUS IN THE WESTERN HEMISPHERE

Abstract

Numerous species of the family Palaemonidae (Crustacea, Decapoda) populate the Pacific and Atlantic littoral from the southern U.S.A. to northern Argentina and Chile. These crustacea provide interesting material for faunistic studies because of their special geographic distribution. Their migrations in very recent times have given rise to forms and varieties exhibiting relative features.

Macrobrachium olfersii is a species widely distributed along the eastern coast of the Americas. Allied species are found off the West Indies and the northern coast

of South America. Along the Pacific coast of Central America and Mexico there are also species obviously related to M. olfersii.

The present communication aims at the determination of the extent to which species of the group olfersii constitute a natural assemblage as shown from their geographic distribution and lines of invasion of new territories such as the river basins along the Pacific Ocean.

PROBLEMES DE L'IDENTIFICATION DES ESPECES AMERICAINES D'UN GROUPE DE PALAEMONIDAE DU GENRE Macrobrachium

Résumé

De nombreuses espèces appartenant à la famille des Palaemonidae (Crustacea, Decapoda) peuplent les eaux des côtes atlantique et pacifique de l'Amérique, du sud des Etats-Unis au nord de l'Argentine et du Chili. Du fait de leur distribution géographique particulière ces crustacés revêtent un grand intérêt du point de vue de la recherche faunistique. Les migrations intervenues á des époques trés récentes ont donné lieu à diverses formes et variétés, qui présentent des traits de parenté remarquables.

Macrobrachium olfersii est une espèce très répandue sur la côte orientale de l'Amérique. On rencontre des espèces affines dans les eaux des Antilles et de la partie septentrionale de l'Amérique du Sud. La côte pacifique de l'Amérique centrale et du Mexique héberge elle aussi des espèces dont la parenté avec M. olfersii est manifeste.

La présente communication a pour objet de déterminer la mesure dans laquelle les espèces du groupe olfersii constituent un ensemble naturel, et d'établir la distribution géographique et les lignes d'invasion de nouveaux territoires, ainsi que les bassins hydrographique du littoral pacifique.

1 INTRODUCCION

La vertiente atlántica de América, desde Florida hasta el norte de Argentina y la del Pacífico, desde Baja California hasta Ecuador, contiene en sus cuencas hidrográficas un grupo natural de especies de Palaemonidae del género Macrobrachium, cuya especie representante, M. olfersii (Wiegmann), ha dado una serie de rasgos que más o menos modificados, son el denominador común del grupo. La variabilidad, distribución geográfica y relaciones filogenéticas de estas especies plantean problemas interesantes que nosotros abordamos, iniciando con esto una serie de estudios de los Palaemonidae de México.

M. olfersii (Wiegmann, 1836), especie con una larga lista sinonímica, es un langostino muy singular y fácil de reconocer; sus apéndices quelados más conspicuos, correspondientes a los pereiópodos del segundo par, nos han servido de punto de partida para el establecimiento de la variabilidad de la especie y para la separación de nuevos taxa.

El material examinado ha sido colectado por nosotros de las costas mexicanas del Golfo de México y del Pacífico. El estudio comparativo se ha realizado con ejemplares de nuestra propia colección; material que nos fue enviado por el Dr. Alfred Smalley de la Universidad de Tulane, y con la información de los trabajos de Holthuis (1952), Alves (1963), Hart (1961), Hedgpeth (1949), Sawaya (1946), Hay (1903), de Saussure (1858), Ortmann (1897, 1902) y otros autores.

Las especies mexicanas del grupo olfersii del género Macrobrachium si bien no tienen un gran significado comercial, constituyen parte importante en la dieta de los pobladores indígenas de las cuencas hidrográficas habitadas por este crustáceo. El complemento proteínico que se requiere en la alimentación de estas gentes, es buscado afanosamente en los ríos de ambas vertientes de nuestro país, extrayendo de ellos Atyidos, Astácidos y Palaemónidos. M. olfersii no compite en talla con M. carcinus o M. americanum pero por su abundancia o facilidad de captura suele ser muy estimado por los pescadores.

2 OBJETIVOS

En este trabajo pretendemos demostrar que las distintas muestras de M. olfersii obtenidas de localidades distintas de nuestra vertiente del Golfo evidencian una cierta variabilidad en los rasgos del pereiópodo mayor del segundo par. Al consignar los hechos observados, aportamos datos para establecer los límites de la especie en cuanto a este carácter. El hallazgo de una forma nueva de Macrobrachium en las costas de Oaxaca y Colima nos induce a consignar rasgos de parentesco con M. olfersii y por ampliación, con varias especies de las Antillas, Colombia y Venezuela, así como de Baja California. Todas estas especies presentan rasgos comunes entre sí, lo cual nos ha llevado a considerar la existencia de un grupo natural que parece reconocer en M. olfersii un origen, porque comparten de esta forma, características de los apéndices del segundo par. Proponemos denominar a este grupo conjunto de especies Grupo olfersii, y en él podrían quedar consideradas las siguientes:

1 - Macrobrachium digueti (Bouvier, 1895), localizada en el litoral Pacífico en el sur de Baja California.

2 - Macrobrachium faustinum (de Saussure, 1857), que se localiza en diversas localidades de las Antillas.

3 - Macrobrachium acanthochirus Villalobos, 1966, localizada en cuencas restringidas de la vertiente pacífica, entre Oaxaca y Colima.

4 - Macrobrachium crenulatum Holthuis, 1950, localizada en Panamá, Venezuela, Jamaica, Trinidad y Santo Domingo.

5 - Macrobrachium hancocki Holthuis, 1950, procedente de Costa Rica, Colombia, Panamá, Galapagos e Isla de Cocos.

3 DESCRIPCION

3.1 M. olfersii y sus características diagnósticas

Rostro alcanzando el extremo del pedúnculo antenular; margen superior con 12-15 dientes, 4-5 de los cuales colocados detrás de la órbita. Distancia entre el primer diente y el diente posterior de la órbita, menor que un tercio de la longitud total del caparazón. Dientes regularmente dispuestos. Margen inferior con tres dientes, a veces cuatro.

Telson 1/2 tan largo como la sexta somita abdominal, escafocerito algo menos que tres veces tan largo como ancho, pereiópodos del primer par rebasando con 1/3 del carpus más allá del escafocerito. Dedos tan largos o ligeramente más cortos que la palma. Carpus dos veces tan largo como la quela. Merus 4/5 de la longitud del carpus.

Pereiópodos del segundo par muy desiguales; el mayor alcanza con todo el carpus y una pequena parte del merus, más allá del escafocerito. Dedos, especialmente el dactylus, incurvados, dejando un espacio entre los bordes cortantes, Holthuis (1952). Borde cortante de los dedos con un diente mayor en el tercio proximal, el resto hasta el extremo, con pequeños dientes espaciados. Entre la base y el diente mayor del dedo inmóvil tres pequenos dientes muy juntos y pequeños.

3.1.1 Variabilidad de sus caracteres La variabilidad de la especie es poco aparente en los rasgos correspondientes a la dentición del rostro, así como el alcance de éste con respecto al tercer artejo del pedúnculo antenular (tercio distal). La proporción del caparazón con respecto a la distancia entre el primer diente y el borde orbital se sostiene más o menos en 1/3. La longitud de la sexta somita es apenas 2/3 de la del telson. Las proporciones del escafocerito con respecto a las de los pereiópodos del primer par se mantienen más o menos constantes. En cuanto a la dentición de los bordes cortantes de la quela del pereiópodo del primer par, hemos visto que mantienen una posición semejante a la descrita para M. faustinum; sólo hemos encontrado diferencias entre el número de dientes que existen entre el diente mayor y el extremo distal del dedo.

Las diferencias que hemos notado, radican en la proporción de los podómeros del apéndice mayor del segundo par de pereiópodos. Para ponerlas de manifiesto presentamos el Cuadro I.

Los rasgos que se mantienen constantes corresponden a la relación del escafocerito con el merus, pues en pocas ocasiones vimos que la escama antenal se proyecte más allá del segundo tercio distal del artejo meropodial. La longitud del isquiopodio por lo regular se mantiene ligeramente mayor que la mitad del merus. Pero este último artejo puede ser ligeramente menor o ligeramente mayor que el carpopodio y la misma proporción puede guardar con dactylus. Por lo que respecta al carpus, este podómero es el que aparenta tener una mayor variabilidad en cuanto a forma y proporciones; con respecto a la quela, puede ser un término de variabilidad, puesto que su forma y proporciones, así como la disposición de las espinas de la mano y los dientes de los bordes cortantes de los dedos, aparecen con modificaciones que aisladamente nos podrían conducir a interpretaciones erróneas de identidad (Figs. 1 y 2).

3.1.2 Distribución geográfica La amplia distribución de M. olfersii nos conduce a considerarlo como el tronco original del grupo olfersii. La especie se extiende por todos los sistemas hidrográficos de la vertiente atlántica, desde el norte de Tamaulipas, México, hasta el sur de Brasil. Su localización en Florida se supone que es artificial (Hedgpeth, 1949; Schmitt, 1933; Holthuis, 1952). Dados los hábitos de esta especie, francamente lóticos, con altas exigencias de oxígeno, en México hemos encontrado la especie en las cabeceras de las cuencas hidrográficas, en ocasiones hasta 150 km de la desembocadura de los ríos.

CUADRO 1

Variabilidad del apéndice mayor del 2^{o} par de pereiópodos de Macrobrachium olfersii

Proporciones	Arroyo Las Lajas – Tehuantepec, Oax. I	Arroyo Las Lajas – Tehuantepec, Oax.II	Río Bobos, Mtz. de la Torre, Ver.	Río San Marcos La Ceiba, Pue.	Gruta de Don Luis Hacienda de Rosarito, Teapa, Tab.	El Escolín, Papantla, Ver.
Alcance del extremo distal del escafocerito	Extremo distal del carpus	2^{o} tercio distal del carpus	2^{o} tercio distal del carpus	2^{o} tercio distal del carpus	2^{o} tercio distal del carpus	2^{o} tercio distal del carpus
Proporción del isquio	Ligeramente mayor que la mitad del merus; la mitad del carpus	Mayor que la mitad del merus; la mitad del carpus	Igual que la mitad de la longitud del merus	Mayor que la mitad del merus	2/3 la longitud del merus; la mitad del carpus	La mitad del merus; la mitad del carpus
Proporciones del merus	De la misma longitud que el carpus; igual a la longitud del dedo inmóvil	Ligeramente menor que la longitud del carpus; menor que la longitud del dedo inmóvil	Ligeramente mayor que la longitud del carpus; ligeramente mayor que la longitud del dactylus	De la misma longitud que el carpus; menor que la longitud del dactylus	Ligeramente menor que el merus; francamente menor que el dactylus	Igual que el carpus y menor que el dactylus
Proporciones del carpus	cabe 2 ½ veces en la longitud de la quela	2 ⅓ veces en la longitud de la quela	2 veces en la longitud de la quela	Menor que la mitad de la longitud de la quela	½ de la longitud de la quela	2 ½ veces la longitud de la quela
Quela	Longitud de la palma mayor que el dactylus	Longitud de la palma menor que el dactylus	Francamente mayor que la longitud del dactylus	Mayor que la longitud del dactylus	Longitud de la palma menor que el dactylus	Longitud de la palma mayor que el dactylus
	Anchura mayor ligeramente menor que la longitud del carpus	id.	Anchura mayor francamente menor que la longitud del carpus	Anchura de la quela menor que la longitud del carpus	Anchura de la quela 2/3 la longitud del carpus	Anchura mayor 2/3 la longitud del carpus
	Longitud del dactylus cabe 2 ½ veces en la longitud de la quela	id.	Longitud del dactylus menor que la mitad de la longitud de la quela	Longitud del dactylus igual a la mitad de la quela	Longitud del dactylus mayor que la mitad de la longitud de la quela	Longitud del dactylus igual a la mitad de la longitud de la quela
	Anchura del carpus ¼ de la longitud de la quela	Anchura ligeramente menor que ¼ la longitud de la quela	Anchura ligeramente menor que ¼ de la longitud de la quela	Anchura del carpus menor que ¼ de la longitud de la quela	Anchura del carpus menor que ½ la longitud de la quela	Anchura del carpus ⅕ de la longitud de la quela
	Espinulación: Espínulas del margen interno acompañadas o nó con filas de espinas submarginales	Espínulas del margen interno no acompañadas por espinas submarginales	Las marginales espaciadas y sin fila submarginal	Fila submarginal incompleta a veces completa	Con fila submarginal de espinas	Fila submarginal de espinas incompleta

Las peculiares condiciones topográficas e hidrológicas del Istmo de Tehuantepec han permitido a *M. olfersii* (Fig. 3) extender su distribución hasta muy cerca del litoral Pacífico y creemos que esta corriente bien pudo poblar ríos de la vertiente del Pacífico.

3.2 *M. faustinum* y sus rasgos característicos

Los caracteres de la especie están amplia y acuciosamente descritos en la monografía de Holthuis (1952). Los rasgos y proporciones del pereiópodo mayor del segundo par se pueden observar claramente en el esquema presentado por de Saussure (1858). Se puede comentar que el apéndice se distingue por su forma esbelta y que las proporciones entre merus y carpus, a pesar de conservarse como en *M. olfersii*, resaltan como dos artejos cuyo grosor es 7½ veces menor que la longitud de la quela (en *M. olfersii* esta proporción es de 1 a 4). Por otra parte, el carpus es tan largo como la mitad de la longitud de la quela, hecho que sólo en forma ocasional lo encontramos en una población procedente de una gruta en el Estado de Tabasco, tal vez concomitante con los hábitos trogloxenos de este ejemplar.

3.2.1 Distribución geográfica de Saussure (1858) sitúa la localidad tipo en Haití y extiende su distribución a las Antillas. Holthuis (1952) analiza las localidades del material por él examinado y deslinda una distribución geográfica para las Antillas exclusivamente.

3.3 *M. digueti* y sus rasgos diagnósticos

No obstante que la descripción de Bouvier (1895) es realmente concisa, la Fig. 2 de su trabajo nos ha servido para considerar cuidadosamente que *M. digueti* en el sentido de Holthuis (1952) no corresponde a la especie original de Bouvier. El material de Palaemonidae procedente de Baja California que tenemos en nuestras manos, aunque no procede de la localidad tipo de *M. digueti*, sino de San José del Cabo en el extremo de la península, se ajusta estrechamente a los rasgos y medidas consignadas por Bouvier.

M. digueti merece cuidadosa revisión, para la cual convendría colectar topotipos en Mulegé, Baja California; pero ahora, sirva la ocasión para hacer algunas anotaciones obtenidas de mi material, al cual identifico como *M. digueti* (Bouvier, 1895).

Diagnosis Pereiópodos del segundo par con quela tan ancha como dos tercios de la longitud del dactylus. Longitud de la región palmar ligeramente mayor que la anchura de la quela. Merus 4/5 de la longitud del dactylus. Carpus corto, tan ancho como la mitad de la longitud del dactylus. Superficie externa de la palma provista de gruesos tubérculos espinosos.

Descripción El rostro se extiende hasta el extremo distal del tercer artejo del pedúnculo antenular; su dentición es $\frac{6+9}{4}$; un ejemplar acusó $\frac{5+9}{3}$. La distancia entre el primer diente y el borde orbital cabe 3½ veces en la longitud del caparazón.

Longitud de la sexta somita es 2/3 de la del telson; par proximal de espinas dorsales de éste a ½ de la longitud.

Longitud de la escama antenal 2 2/3 la anchura. Pereiópodos del primer par alcanzando con dos tercios a la mitad del carpus, el extremo distal del escafocerito. Dedos de la quela tan largos como la palma. Merus 3/4 de la longitud del carpus. Apéndice mayor del segundo par de pereiópodos robusto y corto, con fuertes tubérculos en el extremo distal del merus, el carpus y la quela; esta última es aplanada y con el perfil de la palma cuadrangular; dedo inmóvil con el borde interno (superior) recto, base tan ancha como la mitad del dactylus; borde cortante con tres pequeños dientes muy juntos, cerca de la articulación con el dactylus; después, seis dientes conspicuos de tamaño decreciente hacia el extremo distal del dedo; el resto del borde con una cresta roma, en la cual

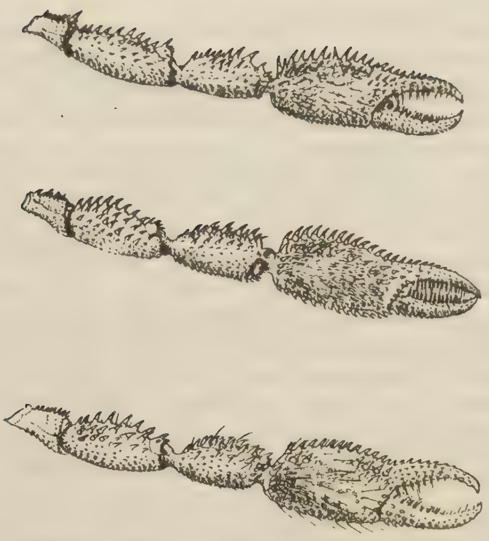


Fig. 1 Variabilidad del quelípedo mayor de los pereiópodos del segundo par de Macrobrachium olfersii; ejemplares del Río San Marcos, La Ceiba, Puebla, México.

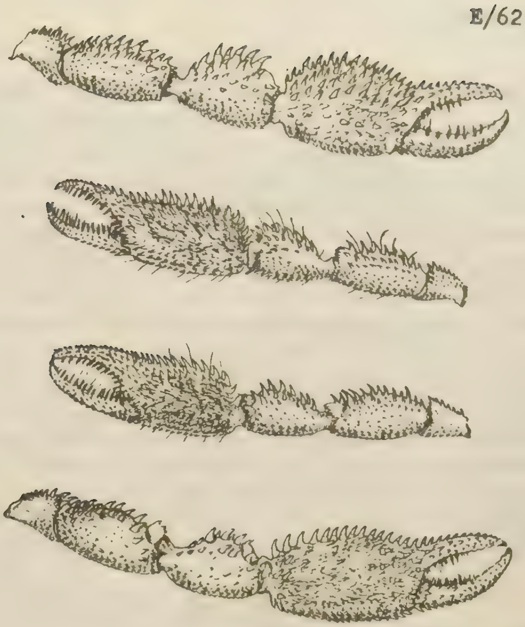


Fig. 2 Variabilidad del quelípedo mayor de los pereiópodos del segundo par de Macrobrachium olfersii; ejemplares del Río Las Lajas, Tehuantepec, Oaxaca, México.

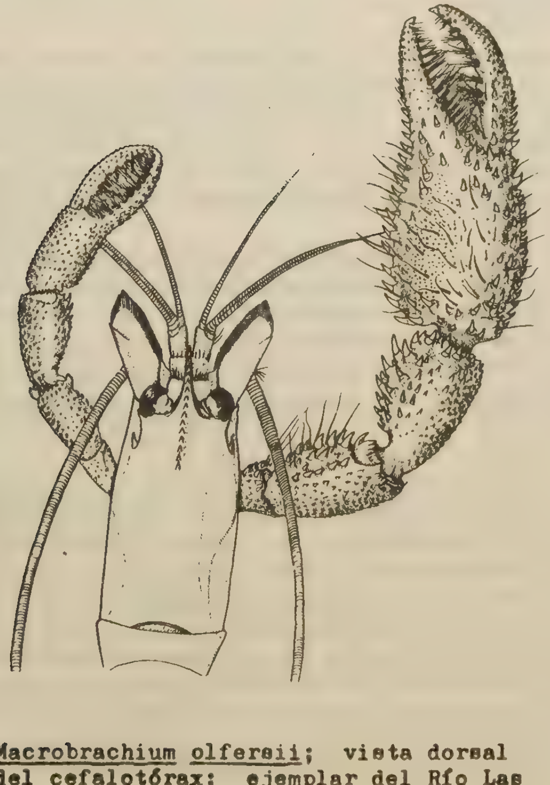


Fig. 3 Macrobrachium olfersii; vista dorsal del cefalotórax; ejemplar del Río Las Lajas, Tehuantepec, Oaxaca, México.

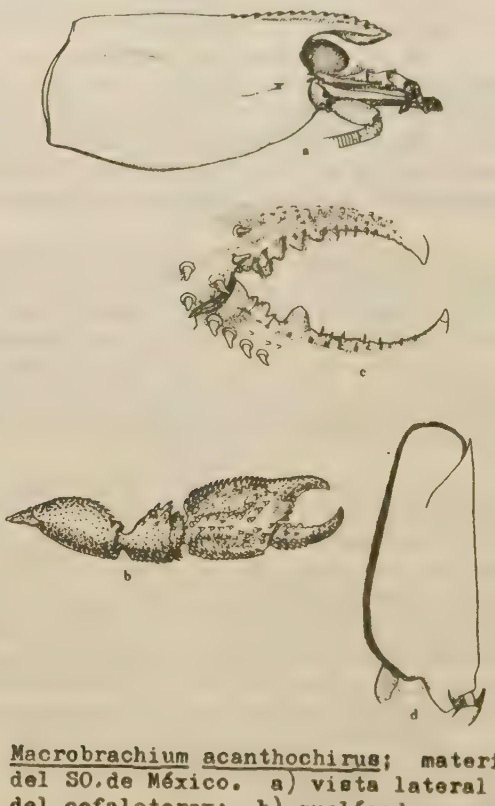


Fig. 4 Macrobrachium acanthochirus; material del SO. de México. a) vista lateral del cefalotorax; b) quelípedo mayor; c) dentición de los bordes cortantes del quelípedo mayor; d) escafocerito.

apenas se destaca una dentición. Borde cortante del dactylus con dos o tres pequeños dientes muy juntos, semiesféricos, separados un tanto del borde articular proximal y del diente mayor, que se destaca por su tamaño y forma en el primer tercio de la longitud del dedo. Espinulación del borde interno (superior) de la región palmar con una sola fila de tubérculos espiniformes regularmente espaciados; la espinulación de la región dactilar de la quela, es una continuación de la serie palmar, pero las espinas están más juntas, más inclinadas hacia adelante y cada vez más pequeñas hacia la parte distal. La cara superior o externa del dedo inmóvil, así como la inferior, con la superficie provista de espínulas pequeñas, recostadas sobre ella. La misma cara del dactylus con la mitad proximal provista de gruesos tubérculos espiniformes y la distal con espínulas semejantes a la del dedo opuesto. Cara superior o externa de la región palmar con una zona submarginal al borde interno desprovista de espinas, pero densamente cubierta de pelos; otra zona semejante desprovista de espinas se localiza cerca del borde opuesto, el cual además posee dos filas submarginales de espinas; la fila de espinas que limita este borde externo o inferior comprende 24 espínulas, dispuestas muy juntas a todo lo largo de la región palmar, ya que la dactilar posee unas 34 más pequeñas y menos regularmente dispuestas.

3.3.1 Distribución geográfica En virtud de la modificación del concepto de esta especie, tenemos que apartarnos de la distribución geográfica consignada por Holthuis (1952) y restringirla por ahora a las cuencas hidrográficas de la costa oriental de la península de Baja California, desde San José del Cabo, hasta Mulegé. Dadas las condiciones geográficas de Baja California, las localidades estarían ampliamente separadas por zonas áridas.

3.4 M. acanthochirus y sus rasgos diagnósticos (Fig. 4)

En el momento de redactar el siguiente trabajo, aún se encontraba en prensa la descripción original de esta especie y debido a que dicha descripción verá muy en breve la luz, se anota la especie como ya descrita. Los ejemplares que sirivieron para el estudio, fueron los primeros dados a conocer, no obstante que otro especimen estaba depositado en la colección del Dr. Federico Bonet, quien nos lo cedió para su estudio, junto con otros palemónidos procedentes de Baja California, que identificamos como M. digueti.

Diagnosis Pereiópodos del segundo par con quela tan ancha como la longitud del dactilopodio. La longitud de la región palmar igual o ligeramente menor que la anchura. Merus tan largo como el dactylus. Superficie externa de la palma de la quela provista de conspicuos tubérculos espinosos, excepto en dos zonas submarginales de la cara externa, en las que sólo hay una densa pubescencia. Tubérculos marginales internos de la región dactilar muy juntos. Otros detalles morfológicos se encuentran en el Cuadro II y en la descripción original (Villalobos, 1968).

3.4.1 Formas relativas en México La única especie con la cual M. acanthochirus tiene estrechas relaciones es M. digueti. Su parentesco es tal que hemos estado inciertos hasta dónde M. acanthuchirus es una nueva especie y si en cambio encuadraría mejor en el rango de subespecie de M. digueti. Conservaremos tentativamente el status inicial a reserva de avocarnos de inmediato a una revisión completa del material disponible y del que obtengamos en exploraciones de la costa pacífica realizadas con este fin. La comparación entre M. acanthochirus, M. digueti y M. olfersii, ha quedado señalada en el Cuadro II y ahí el lector podrá darse cuenta de la cercanía de las formas mencionadas. Un ejemplar de Colima, localidad al norte de Tehuantepec y dentro del área geográfica de la localidad tipo, coincide completamente con los caracteres de M. acanthochirus, excepto la dentición de los bordes cortantes del quelípedo mayor del segundo par de pereiópodos, en los cuales ya se presentan rasgos de M. digueti.

CUADRO II

Cuadro comparativo de tres especies del grupo olfersii

M. acanthochirus	M. digueti	M. olfersii
Rostro se extiende hasta extremo distal del 3er artejo del pedúnculo antenular	Rostro se extiende hasta extremo distal 3er artejo del pedúnculo antenular	Rostro alcanzando el extremo del pedúnculo antenular
Dentición $\frac{5 + 10}{4 \text{ a } 5}$	Dentición $\frac{6 + 9}{4}$	Dentición $\frac{4 \text{ a } 5 + 8 \text{ a } 10}{3 \text{ a } 4}$
Distancia entre primer diente rostral y borde anterior del caparazón 3 1/2 a 4 veces la longitud de éste	Distancia entre primer diente rostral y borde anterior del caparazón 3 1/2 veces la longitud de éste	Distancia entre primer diente rostral y borde anterior del caparazón menor que 1/3 la longitud total del cefalotorax excepto rostro
Pereiópodo del primer par alcanzando con 2/3 del carpus el extremo distal del escafocerito	Pereiópodo del primer par alcanzando con 2/3 o 1/2 del carpus el extremo distal del escafocerito	Pereiópodo del primer par rebazando con 1/3 del carpus más allá del escafocerito
Longitud del merus casi igual que el carpus (1/8) de diferencia	Merus 3/4 de la longitud del carpus	Merus 4/5 la longitud del carpus
Quelípedo mayor del pereiópodo segundo: anchura de la quela igual que la longitud del dactilipodio	Quelípodo mayor del pereiópodo segundo: anchura de la quela 2/3 la longitud del dactylus	Quelípedo mayor del pereiópodo segundo: anchura de la quela 1/2 y ocasionalmente 2/3 de la longitud del dactylus
Longitud de la región palmar igual que la anchura	Longitud de la región palmar ligeramente mayor que la anchura de la quela	Longitud de la región palmar menor que la anchura
Merus de la misma longitud del dactylus	Merus 4/5 de la longitud del dactylus	Merus de la misma longitud que el dactylus
Carpus más ancho que la 1/2 de la longitud del dactylus y su longitud 2/3 la del dedo móvil	Carpus tan ancho como 1/2 de la longitud del dactylus y su longitud es 3/4 de la longitud del dactylus	Carpus la mitad de la longitud del dactylus y su longitud mayor que la del dactylus
Longitud del dactylus menor que la de la longitud palmar	Longitud del dactylus igual a la longitud de la región palmar	Longitud del dactylus generalmente menor que la de la longitud palmar
Dientes de los bordes cortantes de los dedos: a) dedo inmóvil 3 proximales pequeños 3 grandes proximales b) dactylus 3 proximales pequeños 1 grande	Dientes de los bordes cortantes de los dedos: a) dedo inmóvil 3 proximales pequeños 6 dientes grandes b) dactylus 2 proximales pequeños 1 grande	Dientes de los bordes cortantes de los dedos: a) dedo inmóvil 1 diente mayor en el tercio proximal varios dientes muy pequeños espaciados 3 dientes pequeños proximales muy juntos b) dactylus 1 diente mayor en el tercio proximal varios dientes pequeños espaciados

Las relaciones entre la especie que ahora se discute y M. olfersii, podrían establecerse con poblaciones de la costa pacífica, en las que se puede observar cierto acortamiento del carpus y un desarrollo de los tubérculos espinosos de la quela y de los podómeros meropodial y carpal.

3.4.2 Especies relativas en Centro y Sudamérica En nuestro criterio, dos son las especies relativas en Centro y Sudamérica: M. hancocki y M. crenulatum; ambas están estrechamente ligadas entre sí como lo demuestran los caracteres del rostro, el caparazón, el abdomen y el telson (Holthuis, 1952). La separación específica se establece con rasgos de los apéndices, sobre todo los de los pereiópodos del segundo par (Holthuis, 1952). En ambas especies se nota un alargamiento de la porción palmar de la quela mayor de los pereiópodos del segundo par; mientras que la porción dactilar proporcionalmente es más corta que en las otras especies del grupo olfersii. La disposición de los dientes de los bordes cortantes de los dedos es más parecida a M. olfersii que a M. acanthochirus y a M. digueti; pero la espinulación del quelípedo mayor y la presencia en M. hancocki de una zona desprovista de tubérculos espinosos y cubierta con pelos cortos, delgados y numerosos, hasta dar la apariencia de una vellosidad aterciopelada, puede ser un rasgo de relación con las formas mexicanas.

4 DISCUSION Y CONCLUSIONES

Varias especies de Palaemonidae del género Macrobrachium son reunidas de acuerdo con nuestro criterio en un grupo natural, cuyos caracteres tienen como denominador común los de M. olfersii. No estamos posibilitados, por el momento, para dar los rasgos diagnósticos del grupo; pero los caracteres de los pereiópodos del segundo par nos ofrecen buenas bases para considerar a las especies afines.

Sobre la base de los hallazgos actuales de M. olfersii en localidades muy distantes entre sí, podríamos considerarla como una especie de amplia distribución geográfica. Sus vías de invasión a nuevos territorios de la vertiente pacífica, las ha podido establecer a través del Istmo de Tehuantepec y a través de zonas de posibilidades semejantes en el sur de América Central (Fig. 5).

Las especies de la vertiente pacífica adquieren un tipo especial de estructura en los quelípedos, cuyo patrón en la parte mexicana es el de M. digueti.

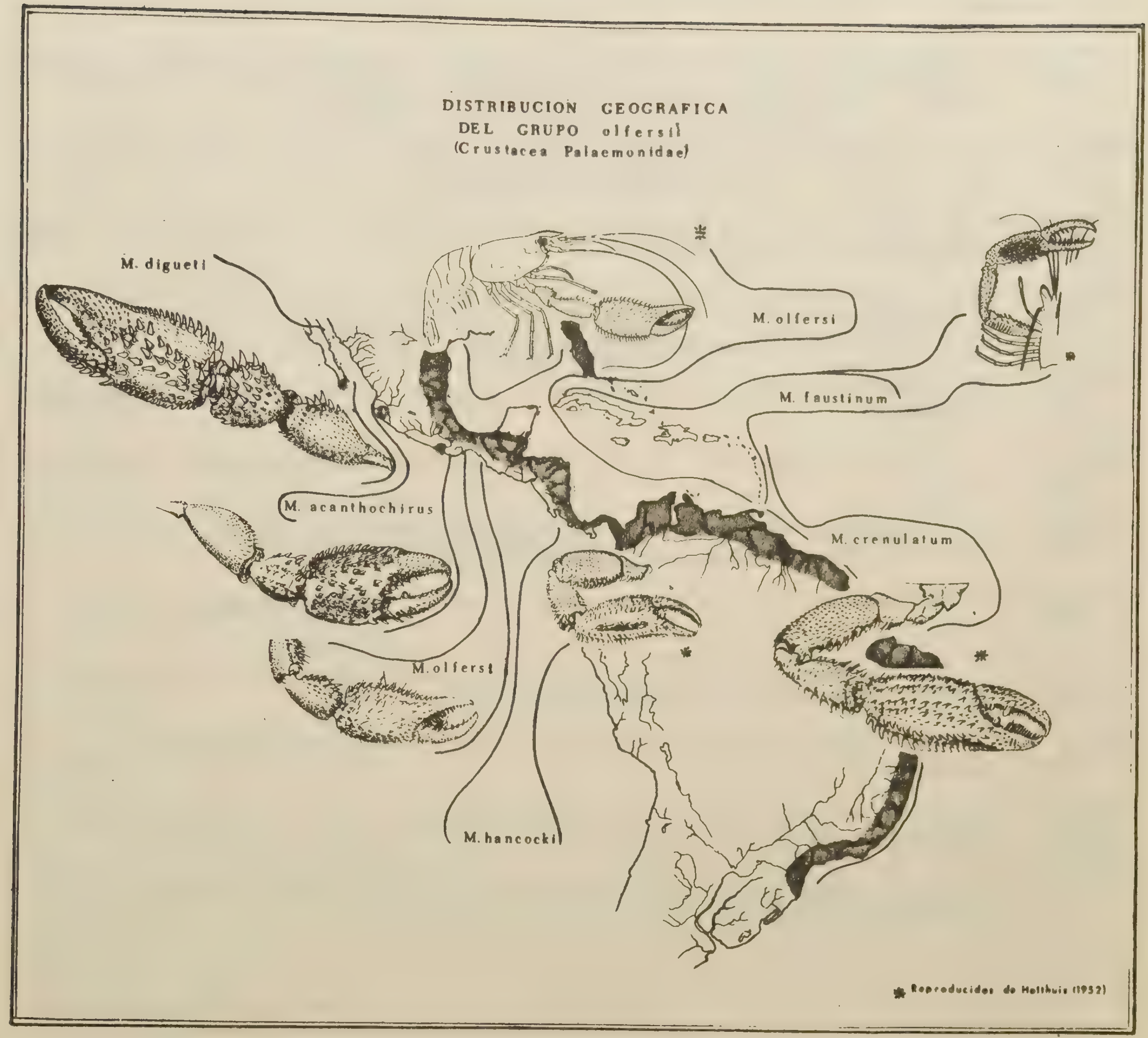
En la costa pacífica de Centro América y norte de Sudamérica, la especie M. crenelatum es la más conservada de los rasgos de M. olfersii.

De todo lo anterior, se puede concluir que la variabilidad de M. olfersii obedece por una parte, a los hechos establecidos por Holthuis (1952) para los Palemonidae; pero además, creemos que la amplia distribución geográfica, da ciertas posibilidades a la especie para adquirir rasgos diferentes del patrón original, tal como sucede en los ejemplares de nuestra colección (Fig. 3), provenientes del Istmo de Tehuantepec.

La presencia de especies afines al grupo, que pueblan la costa pacífica, induce a pensar en una antigua dispersión del tronco original, a través del mismo camino en el Istmo de Tehuantepec, hasta alcanzar a establecerse en la costa oriental de la Península de Baja California, habiendo tenido tales especies suficiente tiempo para una evolución independiente.

M. digueti reasume su original identidad, al agrupar a dicha especie ejemplares colectados en San José del Cabo, cuyos caracteres concuerdan con la descripción original de Bouvier.

M. hancocki y M. crenulatum son especies muy cercanas entre sí, que conservan rasgos de M. olfersii.



DISTRIBUCION GEOGRAFICA
DEL GRUPO olfersii
(Crustacea Palaemonidae)

M. digueti
M. olfersi
M. faustinum
M. acanthochirus
M. crenulatum
M. olfersi
M. hancocki
*

* Reproducidos de Holthuis (1952)

Fig. 5 Distribución geográfica y afinidades de las especies del grupo olfersii.

M. faustinum fue probablemente la primera especie que se estableció en las Antillas, lo cuál puede deducirse en razón de su endemismo.

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THE SUITABILITY OF THE ENGLISH PRAWN Palaemon serratus (PENNANT) FOR CULTIVATION - A PRELIMINARY ASSESSMENT

by

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Abstract

Background information with regard to ecology, distribution and method of collection are given for Palaemon serratus, and the published literature is briefly reviewed. The methods of obtaining larvae from mature adults in the laboratory, and the difficulties associated with the maintenance of tank populations of stock prawns are noted. Consideration is given to factors affecting the rearing of young stages, including temperature, salinity, density, cannibalism and food. Growth over several months is followed. Specific points to come out of the study are discussed both on the positive side and also on the negative side, showing where further research is needed. The latter include the need for breeding for specific strains, and the desirability of study of the pathology and biochemistry of the prawn. Scaling-up to a pilot operation is contemplated, as well as economic aspects such as price of the product and cost of rearing. Overall, an optimistic outlook is taken of the biological feasibility of the project, with opinion reserved regarding the economics.

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POSSIBILITES D'ELEVAGE DE LA CREVETTE ROSE (Palaemon serratus Pennant) : EVALUATION PROVISOIRE

Résumé

L'auteur, après avoir exposé les données essentielles touchant l'écologie et la répartition de Palaemon serratus et la technique employée pour recueillir les sujets, et passé brièvement en revue la documentation existante, traite des méthodes adoptées pour obtenir au laboratoire des larves à partir d'individus adultes, et relève les difficultés que pose le maintien en vivier de populations de crevettes. Il étudie les facteurs qui affectent le développement des formes juvéniles : température, salinité, densité, cannibalisme et alimentation. La croissance des animaux est suivie pendant plusieurs mois. Les divers résultats sont examinés sous l'angle tant positif que négatif, de manière à mettre en évidence les domaines nécessitant un complément d'étude. Il apparaît par exemple qu'il faut sélectionner certaines souches et qu'il serait bon d'étudier la pathologie et la biochimie de la crevette. L'auteur envisage la possibilité de passer du stade du laboratoire à celui de l'opération pilote, et se penche sur certains aspects économiques comme le prix du produit et le coût de l'élevage. Dans l'ensemble, il est optimiste quant à la viabilité biologique du projet, mais réserve son opinion pour ce qui est de l'angle économique.

LA ADAPTABILIDAD DEL CAMARON INGLES PALAEMON SERRATUS, PENNANT, PARA EL CULTIVO - DEDUCCIONES PROVISIONALES

Extracto

Se examinan brevemente los antecedentes de que se dispone con respecto a la ecología, distribución y métodos de recogida de Palaemon serratus, así como la literatura publicada sobre el tema. Se indican los métodos que se siguen en el laboratorio para obtener larvas de adultos maduros, y las dificultades relacionadas con el mantenimiento de poblaciones de camarones en estanques. Se estudian los factores que influyen en la cría de formas jóvenes, como son la temperatura, salinidad, densidad, canibalismo y alimentación. Se sigue el crecimiento a lo largo de varios meses. Se examinan puntos específicos del estudio, tanto desde el punto de vista positivo como negativo, para averiguar en qué sector es preciso realizar nuevas investigaciones. Esto incluye la necesidad de criar razas específicas, y la conveniencia de estudiar la patología y bioquímica del camarón. Se estudia la posibilidad de ampliar las operaciones a escala experimental, y aspectos económicos tales como el precio del producto y los gastos que representa la cría. En general, la viabilidad biológica del proyecto se considera de un modo optimista aunque se reserva la opinión en lo que se refiere a su economía.

1 INTRODUCTION

The work which forms the basis of this review is reported in detail in Reeve (1969, 1969a) and was largely accomplished over a period of two years ending in the summer of 1966.

Palaemon serratus was chosen for the initial study because it was native to British coasts (and hence was presumably more amenable to laboratory culture than offshore deeper water animals such as Pandalus borealis) and also because it was the largest of the native shrimps and prawns. Its larval life history had been investigated by Gurney (1924) from plankton samples and by Sollaud (1923) in the laboratory. Forster (1951) and Cole (1958) studied its ecology around British coasts. It has also been used extensively in physiological studies.

The species is found throughout the Mediterranean and only enters British waters at the extreme north of its range, where it has in the past been fished along the south coast of England, Wales and Ireland. In 1964, however, when the study began, prawns were scarce in the areas around the laboratory at Conway in North Wales, and the live mature animals needed had to be transported from the south coast of England. The journey of up to 350 mi (563 km) was made in the minimum possible time, using vehicles which could accommodate bins containing sea water through which oxygen was bubbled.

The initial study, the results of which will be referred to below, was concerned mainly with the location of sources of stock prawns and the procurement and rearing of larvae and post-larvae.

2 STOCK PRAWNS

It was known from the work of Cole (1958) that the period of egg carriage in nature is directly related to temperature. On arrival at the laboratory, berried females (those which had spawned and were carrying their eggs) were therefore gradually accustomed to warm water of up to 20°C. In this way, the duration of egg carriage could be reduced from up to five months in nature to 28 days at 20°C in the laboratory. The fecundity of a prawn was dependent on its size, the largest animals producing over 3000 eggs. The larvae hatched as zoea and did not pass through a stage where they required phytoplankton suspensions for food; they could be separated from the adults by making use of their attraction to light. Maturing females which were taken from the natural environment were able to mate and spawn successfully in laboratory tanks and eventually to produce viable larvae.

Considerable difficulty was experienced in keeping stocks of adult prawns over long periods in laboratory tank populations. One very obvious problem was the susceptibility of a soft newly-moulted prawn to attack from its companions. Although growth was rarely observed in adult stocks, prawns nevertheless continued to moult regularly, the frequency depending on the temperature; at 20°C the mean intermoult period was 21 days. In tanks in which the density of animals was reduced, the survival rate over a period increased. Various forms of cover were offered in which soft animals could take refuge, but these were of little use. Survival rates were higher in stocks of berried females, because they did not moult during the period of egg carriage.

Apart from the mortality of stocks of adults due to cannibalism, mass mortalities also occurred from microbial infection. Prawns were very susceptible to attack of the cuticle, presumably by chitiniferous bacteria. Another symptom known as "white spot", which appeared to be a progressive tissue breakdown from the tail forwards, normally caused death and spread through a population. No detailed work has yet been done on the pathology of these effects, though they appear to be associated with the crowded conditions of laboratory culture, since they were not encountered in commercial catches. Other mortalities which occurred in apparently healthy prawns just before moulting might be associated with feeding deficiences. They were mostly fed on fresh mussel, Mytilus edulis, on the shell.

3 REARING OF YOUNG STAGES

In most of the experiments to be described in this section, larvae were reared in containers with a capacity not exceeding two litres, in sea water which had been filtered and was maintained at a temperature of 20°C and salinity of 32.5°/oo. The nauplii of Artemia were provided as food. Larval growth was measured by increase in length, since the number of larval stages was found not to be constant under varying conditions (Reeve, 1969).

The optimum temperature for larval survival and growth and for metamorphosis, was between 20 and 25°C, varying from brood to brood. At this maximum rate of growth metamorphosis was achieved within about three weeks, and after about seven larval stages had been passed through. Growth rate at any one temperature varied very much between broods. Larvae kept at 30°C did not survive to metamorphosis, and those kept at temperatures below 10°C showed no significant growth.

Salinity tolerance was wide, a 50 percent survival rate resulting after four days following direct transference of larvae from normal sea water to that at salinities ranging from 15-45°/oo. In long-term low-salinity experiments survival was little affected above 23°/oo, although there was some improvement in growth in salinities up to that of normal sea water.

Larvae actively consumed each other, although direct observation could not determine finally whether cannibalism or merely the scavenging of the dead and dying animals was occurring. Indirect evidence, such as the high rates of survival of isolated larvae, and the decimation of the smaller animals in populations of two sizes confirmed, however, that active cannibalism of potentially viable larvae was taking place. An effort to prevent this was made by introducing vigorous aeration in order to evenly distribute and circulate the larvae in the container. The effort failed because anything but the gentlest aeration itself caused high mortality rates.

Provided that there was an adequate supply of food, however, larval cannibalism was not as serious as might have been expected. Even at densities as high as 400/l a survival rate of 28 percent after 26 days from hatching could be achieved, by which time larvae were about to metamorphose and were 8 mm in length. At 20/l the survival rate was 60 percent. Over 90 percent of a population of individuals isolated from each other would survive from hatching through metamorphosis.

A wide variety of foods was offered to newly-hatched larvae of 4 mm in length, ranging from coarse resuspensions of dried Chlorella to chopped ox liver. The most satisfactory food - both from the point of view of ease of preparation and tank maintenance, and also with respect to growth and survival - was undoubtedly the nauplii of Artemia, the brine shrimp. The optimum concentration of live Artemia in the medium was found to be as high as 5-10/ml. During 1966 trouble was experienced with the food, in that certain stocks of brine shrimp eggs, which appeared to originate from Utah, failed to allow the larvae to successfully complete metamorphosis. The nature of the presumed deficiency or possibly toxicity of these Artemia nauplii has not been resolved. It is known that other workers have recently experienced similar problems with Artemia.

On some occasions larval populations were reared beyond metamorphosis. In one experiment, a population was reared at 20°C beyond 150 days from hatching. Following metamorphosis the diet was gradually changed over to fresh mussel. At 150 days, survival had decreased to 13 percent and the mean wet weight had increased from 0.24 mg to 900 mg. This represents a growth rate at least twice as rapid as that encountered in nature around British coasts.

4 DISCUSSION

The information which appears above summarizes some of the points of the study which are comprehensively reported elsewhere (Reeve, 1969, 1969a). On the one hand, in some cases relatively simple solutions have been found to certain potential problems, but on the other hand there are areas requiring further study, and these are brought into sharper focus by the results of the present work.

On the positive side of the balance sheet, the following points may be made. In the first place, all phases of the life-cycle have been shown to be capable of continuance in the laboratory, including the maturation of the gonads of adults, copulation, spawning, egg-carriage, hatching and growth and metamorphosis of larvae, and the growth of postlarvae and juveniles. The complete cycle has not so far been attempted in one population. Even if this proves difficult in the future, it should still be possible to arrange a supply of larvae from adults out of the natural environment throughout most of the year, by taking advantage of the long breeding season. This would be achieved by accelerating the development of maturity and shortening the period of egg-carriage at the beginning of the season, and by slowing down the process towards the end of the breeding season, by raising or lowering the water temperature in which the animals were kept after being brought into the laboratory. The maintenance of high temperatures in the laboratory sea water supply also facilitated the speeding up of the growth rate of the young stages, by provision of a year-round growing season. The net result is the attainment, within six months, of a size which would require over a year in nature.

The palaemonids' habit of carrying their spawned eggs confers certain advantages to a would-be culturist which are not offered by penaeids. The condition and number of the expected hatching may be readily checked and the course of development followed very closely. The resultant larvae hatch directly into a predatory zoea stage, which eliminates the necessity for costly and time-consuming preparations of phytoplankton suspensions. These advantages may be offset to some extent by the fact that fewer eggs are carried - the larger eggs of Palaemon are measured in thousands rather than in the hundred-thousands of the penaeids. Even so, this in turn would appear to be offset by the very high mortalities encountered by penaeid larvae as they pass through a greater number of larval stages. Palaemon larvae may be reared at very high densities with surprisingly good survival rates. It is possible that with improved feeding techniques, the cannibalistic tendencies of the young animals can be considerably reduced even at very high densities. One approach might be to provide larger-sized Artemia nauplii for the late larvae and postlarvae.

As is inevitable in any biological study, the initial work suggests many more avenues of enquiry. Some of the directions which it is important that the research should take in the near future may be briefly touched upon. One of the most interesting and possibly the most rewarding may be the development of genetical strains. It is likely and also desirable that successive generations from the original parents will be capable of being reared through in the laboratory. It is already clear that there is considerable variation between broods, and this could be exploited. A primary requirement would be a strain which combines a fast growth with a high survival rate. The latter property will probably be connected with uniform growth rates within a brood, because it is in situations where some larvae rapidly outgrow others that cannibalism is likely to be more pronounced. A further growth rate requirement is a strain which attains its maximum growth rate at the lowest possible temperature and experiments have suggested that the optimum temperature for growth varies between broods.

Among other qualities to be sought would obviously be resistance to disease, and the whole problem of the pathology of infections in crowded tanks must be investigated from the standpoints both of prevention and cure. This may be associated with other problems of a physiological and biochemical nature, such as an analysis of the variations between the stocks of Artemia in their suitability as food. It will be imperative to know whether food which proves to be of poor quality can be enriched in some way or whether it is actually toxic, whether the quality of the food can be tested other than by bio-assay, and whether food from a particular geographical source may always be relied upon. This sort of work suggests a complete biochemical study of the digestive potential of the prawn. It was clear from the initial work that the adult prawns were not being adequately fed in the laboratory. An analysis of the digestive enzymes should indicate the range of chemical materials capable of being digested and also suggest the composition of a possible synthetic food; for the older animals, at least, this might be desirable, since it might prove impossible to provide vast quantities of a naturally-occurring biological food such as fresh mussel.

The routine rearing of juveniles is still to be considered in detail, and their requirements, like their behaviour patterns, may well be rather different from those of the larvae and early postlarvae. A future need will be the scaling-up of experiments, from laboratory to pilot operations, on a continuous rather than a discontinuous basis This will necessitate the development of techniques to minimize cost and handling. One possibility in the scaling-up process might be semi-automation of the rearing of the young stages. In one experiment Artemia nauplii were allowed to grow in water enriched with algae, while they were at the same time being grazed down by prawn larvae. It should be possible to decide by experimentation on the initial number of Artemia nauplii per prawn larva necessary in the original culture, in order to provide continuously available food for the larvae through metamorphosis and perhaps for a month or more after that time. One of the advantages of the method would be that the food organisms would themselves be increasing in size and would consequently continue to provide suitable food for much larger prawns. Even fully-grown prawns can catch and consume adult Artemia.

It is of course too early to be committed at this stage to the attainment of a commercial farming operation. There are other points of an economic rather than biological nature to be considered. In the first place, there is the question of whether the animal currently being studied is the best possible choice. It seems unlikely that a more suitable local species is to be found. At first sight the larger, faster-growing and highly fecund foreign species such as Macrobrachium and Penaeus appear to be commercially much more attractive propositions, and this might well be the case if they existed in the same geographical region as Palaemon. However, at this stage the maintenance of a species which would be costly and difficult to obtain far away from its natural habitat would probably create many more problems. Much investigative work in the region of origin of the foreign prawn would be an essential prerequisite.

A further consideration in any commercial operation would be the cost of maintaining the high temperatures required for the fastest growth of larvae and juveniles in a hatchery. The transference of late juveniles to fatten off in outside ponds whose temperature was controlled by the climate would inevitably slow down their growth considerably at most times of the year. The problem might not be so serious if it is assumed, as is probably the case, that marketable prawns can be reared within a year under optimum conditions. Such conditions might be the use of the winter period for the indoor hatching and rearing of the young to about half-size or less, followed by the fattening-off period in the spring and summer in outside ponds which might reach a temperature of 20°C in sheltered locations. Another possibility is in the use of the warm-water effluent from electricity generation stations.

In short, although the culture of Palaemon serratus is probably biologically feasible, there are many factors which await resolution before a prediction of its economic feasibility can be accurately judged. It might be considered that with the projected world food shortage, the biological feasibility should take precedence. This possibility aside, however, the fact that intensive cultivation of any marine fish or shellfish is still (with notable exceptions) largely unexplored, would indicate that continued work will provide valuable experience in the field of crustacean cultivation, even if the particular project itself does not mature.

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DISTRIBUTION AND DENSITY OF PREJUVENILE *Penaeus* SHRIMP IN GALVESTON ENTRANCE AND THE NEARBY GULF OF MEXICO (TEXAS)

by

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Abstract

In early 1959 the Bureau of Commercial Fisheries began a study to determine when, from what direction, at what stage of development, under what conditions, and in what quantity prejuvenile shrimp of the commercially important *Penaeus* enter the extensive Galveston (Texas) estuary. The findings were to aid in circumscribing offshore spawning areas and thereby provide information on the degree to which the progeny of shrimp reproducing in each area are nurtured in specific estuaries bordering the northern Gulf of Mexico.

Analysis of over 3,000 samples collected systematically during one biological year revealed: That the frequency of sampling, although high, was insufficient to trace the rapid onshore movement of recently hatched broods of *Penaeus*; that the gross horizontal distribution of *Penaeus* larvae and postlarvae in the Gulf and vertical distribution of postlarvae in Galveston Entrance changed markedly from season to season; that *Penaeus* larvae, rarely occurring within 10 km of shore, were not bottom-dwellers; and that *Penaeus* postlarvae did not frequent the bottom in winter and otherwise were usually more abundant at mid-depths than at the bottom. For estimating density of prejuvenile penaeids, the study's sampling scheme was relatively efficient in controlling spatial variation but comparatively inefficient in accounting for wide temporal variation in organism abundance.

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REPARTITION ET DENSITE DES STADES PREJUVENILES DE CREVETTES Penaeus DANS LA BAIE DE GALVESTON (TEXAS) ET LES SECTEURS AVOISINANTS DU GOLFE DU MEXIQUE

Résumé

Au début de 1959, le service des pêches commerciales des Etats-Unis d'Amérique a entrepris une étude visant à déterminer à quelle date, de quelle direction, à quel stade de développement, dans quelles conditions et en quelles quantités les stades préjuvéniles de Penaeus, crevettes d'importance commerciale, pénètrent dans la vaste baie de Galveston (Texas). Ses conclusions devaient aider à circonscrire les aires de reproduction du large, et à obtenir ainsi des renseignements sur la mesure dans laquelle les descendants des crevettes ayant "frayé" dans chacune de ces aires se développent dans les diverses baies de la partie septentrionale du golfe du Mexique.

L'analyse de plus de 3,000 échantillons recueillis systématiquement pendant une année biologique a révélé les faits suivants : la fréquence de l'échantillonnage, bien qu'élevée, n'a pas permis de suivre le déplacement rapide des Penaeus récemment écloses vers le rivage; la répartition horizontale approximative des larves et postlarves de Penaeus dans le golfe du Mexique et la répartition verticale de postlarves dans la baie de Galveston accusent de nettes modifications saisonnières; les larves de Penaeus, rares à moins de 10 km du rivage, ne sont pas benthiques; enfin les postlarves de Penaeus ne fréquentent pas le fond en hiver et sont par ailleurs plus abondantes à profondeur moyenne que sur le fond. En ce qui concerne l'estimation de la densité des Penaeidae préjuvéniles, le mode d'échantillonnage utilisé pour l'étude est relativement bon pour mesurer les variations spatiales de l'abondance des organismes, mais comparativement inefficace pour rendre compte des fortes variations temporelles.

DISTRIBUCION Y DENSIDAD DEL CAMARON PREJUVENIL Penaeus EN LA EMBOCADURA DE GALVESTON Y EN EL CERCANO GOLFO DE MEXICO (TEXAS)

Extracto

A principios de 1959 la Oficina de Pesca Comercial inició un estudio para determinar el período en que penetran en el amplio estuario de Galveston (Texas) las formas prejuveniles de las especies Penaeus de camarón de importancia comercial, la dirección de que proceden, la fase de desarrollo en que se encuentran, las condiciones en que están y su cantidad. Los resultados ayudarán a circunscribir las zonas de desove frente a la costa, proporcionando información sobre la medida en que la progenie del camarón que se reproduce en cada una de las zonas, se alimenta en los estuarios que bordean la parte septentrional del Golfo de México.

El análisis de más de 3.000 muestras reunidas sistemáticamente durante un año biológico revelaron que: aunque el muestreo se hacia con frecuencia, no bastaba para determinar el rápido movimiento hacia la costa de las larvas de Penaeus después de la eolosión; que la distribución horizontal aproximada de las larvas y postlarvas de Penaeus en el Golfo y la distribución vertical de las larvas en la entrada de Galveston cambiaban mucho de una temporada para otra; que las larvas de Penaeus, que raramente existen a menos de 10 km de la costa, no habitaban en el fondo, y que las postlarvas de Penaeus no frecuentaban el fondo en invierno, abundando más en general a profundidades medias que en el fondo. En la estimación de la densidad de peneidos prejuveniles, el plan de muestreo del estudio era suficiente para controlar la variación espacial, pero insuficiente para explicar la amplia variación temporal de abundancia de organismos.

1 INTRODUCTION

For nearly as long as Gulf of Mexico shrimp resources have yielded what is now our most popular seafood, fishery biologists have sought to delineate the oceanic spawning grounds of the three major species, namely, the brown (Penaeus aztecus Ives), white (P. setiferus Linnaeus), and pink (P. duorarum Burkenroad) shrimps. From numerous observations we may safely infer that each species passes through a similar life cycle, which entails spawning and hatching in the littoral zone of the Gulf, mass shoreward movement of the metamorphosing larvae, rapid growth of the young shrimp through postlarval and juvenile stages in estuarine nursery areas, and, within a year, their return as subadults to the sea where the life cycle is completed (e.g., Weymouth, Lindner and Anderson, 1933; Burkenroad, 1934; and Pearson, 1939). Centers of spawning for the three species have not been precisely circumscribed, and, as a consequence, the spatial relation of these centers to specific inshore nursery areas remains to be established.

In the late fifties the Bureau of Commercial Fisheries Biological Laboratory in Galveston, Texas, undertook a series of projects aimed at broadening our knowledge of the shrimps' early life history. The first of these - the subject of this report - was initiated in early 1959 to determine when, from what direction, under what conditions, at what stage of development, and in what quantity recently hatched shrimps of the genus Penaeus enter Galveston Bay, one of the more important nursery areas along the Gulf coast.

2 THE SAMPLING SCHEME

2.1 The study area

Galveston Entrance together with Bolivar Roads, a major artery for waterborne commerce and one of two areal subdivisions established at the study's outset, is the largest of three tidal passes connecting the Galveston Bay complex with the Gulf of Mexico. Shoaling in the Entrance is controlled by two jetties,the distance between which averages just under 3 km (Fig. 1). Mean depth, excluding the area occupied by ship channels, is approximately 4 m; the ship channels themselves are maintained at about 11 m. Surface area (within the inset of Fig. 1) amounts to almost 35 km^2. Maximum predicted tide differential is roughly 0.5 m and volumetric exchange between the bay and ocean is considerable. The other two tidal inlets are San Luis Pass 48 km to the west and Rollover Pass 32 km to the east. In cross-sectional area both are small relative to Galveston Entrance-Bolivar Roads.

The principal subdivision of the study area included slightly over 1,500 km^2 of the Gulf lying in a semicircle with focal point at Buoy No. 2 just outside the Entrance jetties (Fig. 1). Depths within this subdivision ranged from 0 to 18 m, the average being about 14 m. Bottom topography is unsculptured, of very shallow gradient, and virtually free of natural impediments.

2.2 Intensity of sampling

To provide a network of "offshore" sampling stations from which counts of larvae and postlarvae would indicate routes of penaeid movement into Galveston Bay, we established four 30-km transects radiating seaward from Buoy No. 2 (Fig. 1). Numbered from I to IV, each transect bisected and identified areal sectors of roughly equal size. Positioned along each transect at intervals from the focus of 1/2, 9, 17 and 24 km were four sampling stations. Thus, four tiers of four stations equidistant from the focus identified parcels of water situated at increasing distances from the Entrance. At each station, samples were collected simultaneously at each of two depths, 1½ and 6 m, and occasionally on the bottom, so that every sampling day yielded not less than 32 collections. (The study began with twice the number of radiating transects and corresponding sampling stations, but was reduced by one-half following the second excursion. In the subsequent analyses, data from the first 2 sampling days were consolidated to conform to the modified scheme described above.)

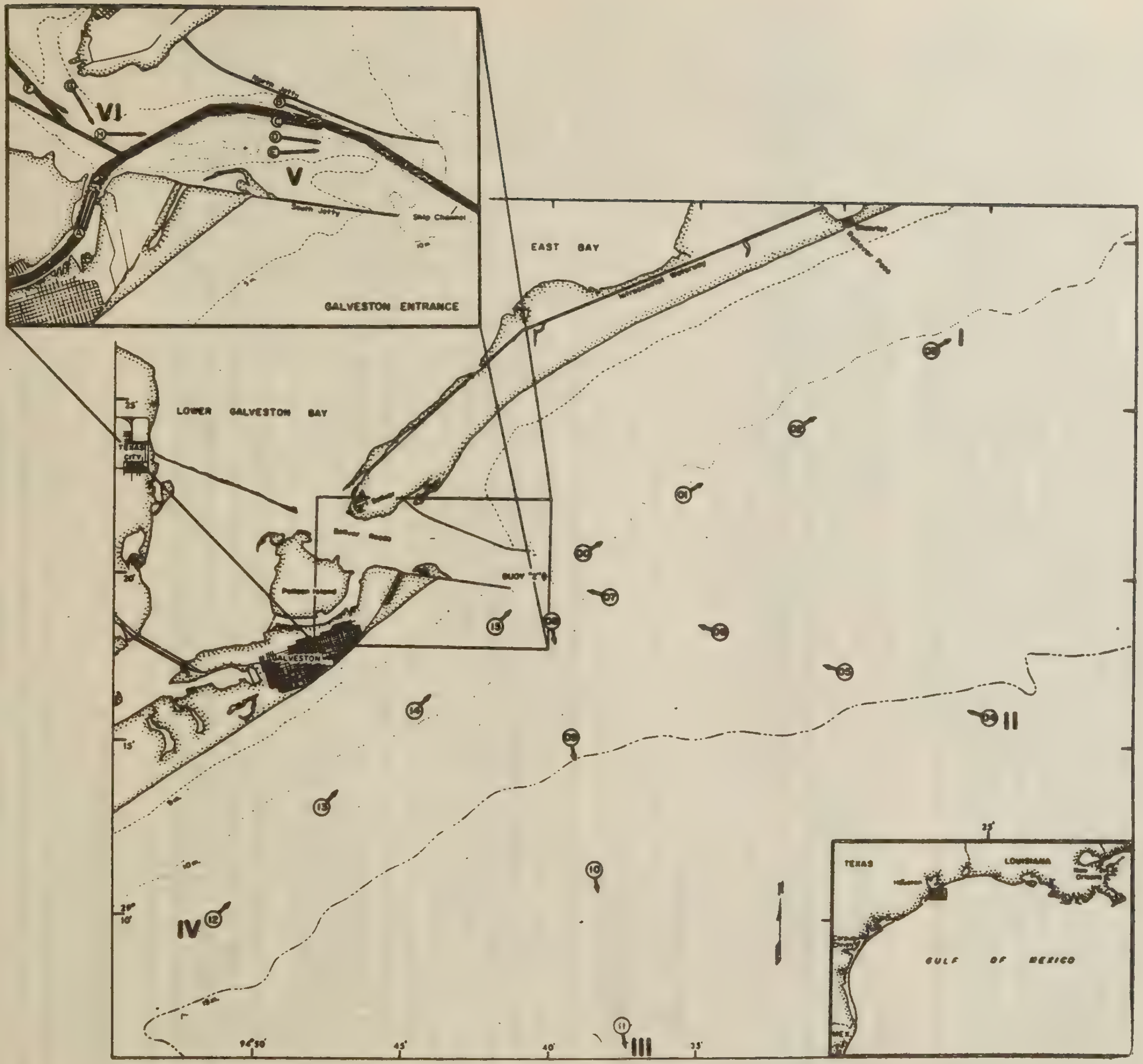
GALVESTON ENTRANCE
North Jetty
South Jetty
Ship Channel
V
VI
EAST BAY
LOWER GALVESTON BAY
TEXAS CITY
GALVESTON
BUOY "2"
I
II
III
IV
TEXAS
LOUISIANA
GULF OF MEXICO
94°50'
45'
40'
35'
25'
20'
15'
29°10'

Fig. 1 Chart of Galveston Entrance and the nearby Gulf of Mexico, showing sampling scheme employed in each of these two subdivisions of the study area.

The Galveston Entrance-Bolivar Roads, or "inshore", subdivision of the general study area was further divided into outer and inner sections, identified in Fig. 1 by Roman numerals V and VI, respectively. In each section we established four sampling stations using navigation buoys and other fixed structures as positioning aids. Samples were taken simultaneously at two depths, 1½ and 6 m, and infrequently at the bottom. Each sampling operation resulted in 16 or more collections until one-fourth of the study had elapsed, after which the number was reduced to 12 with the elimination of two stations in section V.

2.3 Frequency of sampling

Beginning 17 March 1959, and ending 21 March 1960, the study lasted 53 wk - one biological year. The offshore stations were occupied once every 9 days for a total of 40 sampling days and 1,410 collections, the inshore stations once every 3 days for a total of 113 days and 1,594 collections (Table I)[1/]. Sampling offshore required 10 to 12 h depending on sea conditions, whereas sampling inshore took 2 to 3 h. To counter possible bias arising from diel differences in the vertical distribution of planktonic Penaeus, we routinely sampled (with one exception) during daylight. For a comparable reason most (nearly three-fourths) inshore samples were collected on flood tides or adjacent low and high stands.

2.4 Sampling gear

Two double-rigged, Florida-type shrimp trawlers, 14 to 15 m long, provided adequate platforms for all sampling. Sampling gear in a typical operation consisted of a pair of high-speed plankton nets, one fished from each of the two vessel outriggers at each of the two sampling depths, and a small otter trawl towed from a davit for sampling at the bottom.

2.4.1 Description The plankton nets were of the Gulf-V design (U.S. Fish and Wildlife Service, 1959) 40 cm (16 in) in diameter at the mouth, fitted with Atlas flow meters, and constructed of monel cloth having 31.5 meshes per cm (80 meshes/in) and 36 percent open area (Fig. 2). Each net had an absolute open area at the filtering surface 1.67 times the mouth area. Mesh width of 190 μ was sufficiently small to retain the smallest larva we expected to encounter.

The trawl, or "try net", measured 3 m along the headrope, was constructed of 1½-cm (½-in bar) webbing, and had a half-meter No.1 Nansen net fitted over its codend. Its effective mouth opening was slightly less than 2,100 cm^2.

2.4.2 Calibration Before sampling began and at infrequent intervals during the study, we calibrated each of the four flow meters used interchangeably in our several Gulf-V nets. The uncontrollable effects of differential clogging during calibration trials were obviated by simply calibrating the meters outside the nets. This entailed mounting the four meters on a rigid bar and towing the assembly over known distances within the speed range 1.4 to 1.8 m/sec (2 3/4 - 3½ k). Vessel speed, hence distance, was logged by measuring with a stop watch the amount of time it took the vessel and a trailing buoy with combined length of exactly 30 m to pass a spot of flourescein dropped on the sea surface from the bow of the vessel. Each trial run yielded a hypothetical estimate

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1/ In a few instances individual collections were lost due to gear malfunction or other causes. And, where sampling on rare occasions had to be abandoned because of equipment failure or bad weather, whatever material was collected has been excluded from the following analyses. Every attempt was made to facilitate statistical treatment by minimizing difficulties attributable to missing data.

TABLE I

Distribution by subdivision, depth, and month of plankton samples collected in the vicinity of Galveston, Texas, March 1959 - March 1960

Subdivision	Galveston Entrance (6–8 stations)				Gulf of Mexico (16 stations)			
Month	Sampling days	Depth			Sampling days	Depth		
		1½ m	6 m	Bottom		1½ m	6 m	Bottom
1959	Number	Number			Number	Number		
March	6	48	46	0	1	8	8	0
April	10	72	80	0	3	48	48	9
May	13	80	104	49	3	48	48	16
June	12	96	96	5	3	48	48	0
July	8	42	48	0	4	64	64	0
August	9	54	54	11	3	48	48	16
September	8	48	48	7	5	80	80	26
October	9	54	54	8	3	48	48	18
November	7	42	42	7	3	48	48	17
December	10	60	60	10	4	64	64	23
1960								
January	7	42	42	7	2	32	32	12
February	8	46	46	8	3	48	48	17
March	6	36	36	6	3	38	38	12
Subtotal	113	720	756	118	40	622	622	166
Total	113	1,594			40	1,410		
Frequency	Every 3 days				Every 9 days			

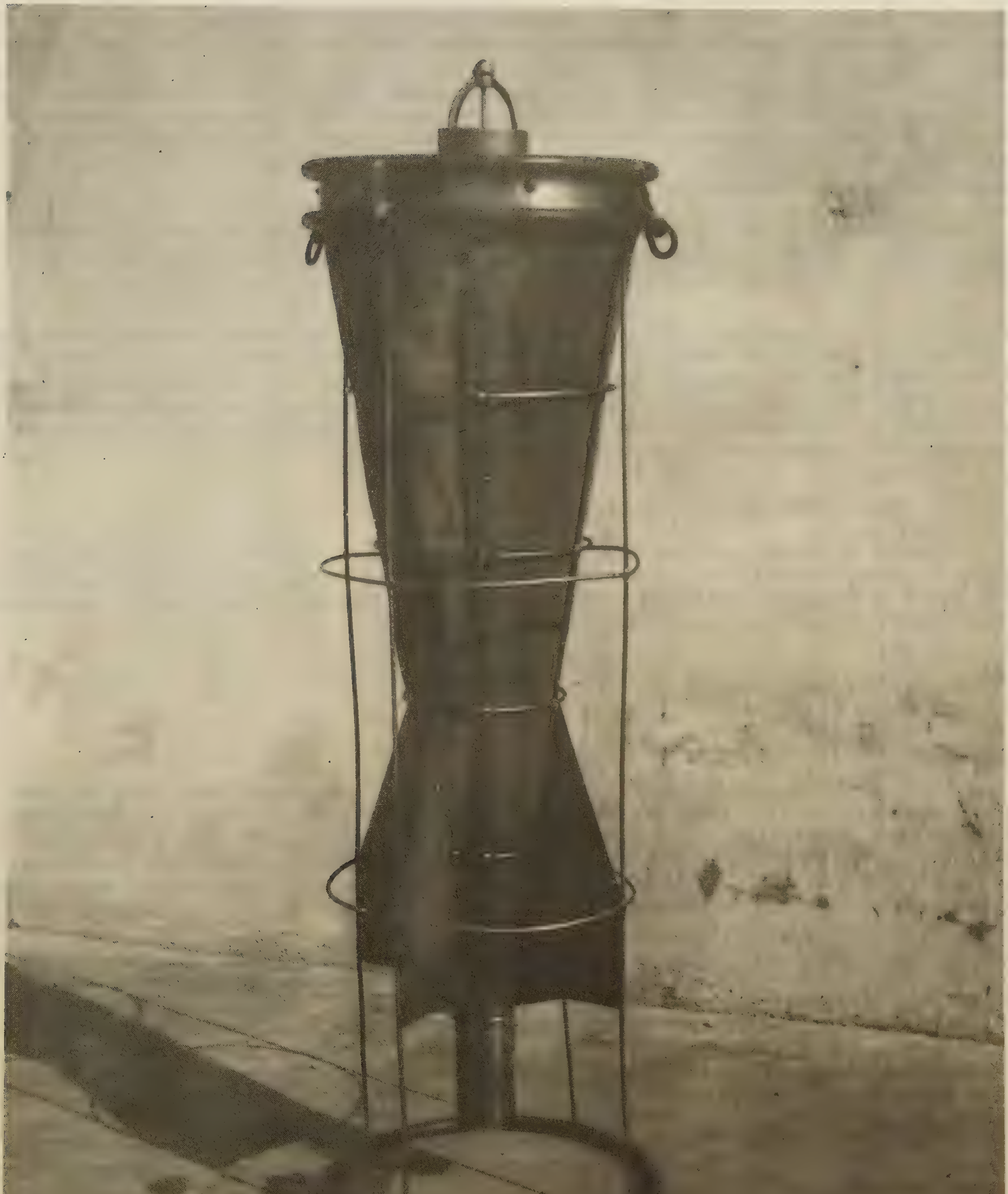

Fig. 2 The high-speed, all-metal, Gulf-V plankton net.

of filtered water volume (distance x cross-sectional area of net mouth) and a corresponding meter reading. The resulting coefficients of the regression of volume on number of meter revolutions were used to standardize for quantitative analysis all subsequent plankton counts. Fig. 3 depicts the plot of a typical set of calibration data. Under normal sampling conditions we assumed that the mouth of the net maintained a perpendicular attitude relative to the direction of haul, that added resistance due to clogging during a haul did not significantly alter rate of vessel headway (i.e., net speed), and that the flow meters accordingly registered only the amounts of water actually passing - at a diminishing rate during each haul - through their respective nets. (See Buchanan-Wollaston (1911) for additional observations on the subject of clogging and net performance).

The volume of water filtered during each haul of the trawl was estimated by the product of the effective cross-sectional area of the net's mouth and the distance of the haul, as measured by the method just described.

2.4.3 Operation Net hauls lasted 10 min and, as stated earlier, were made at 1½ m, 6 m and, infrequently, on the bottom. They originated at and proceeded in the direction from the sampling stations indicated in Fig. 1. Maintaining the Gulf-V nets at their designated sampling depths presented no problem; quick, vertical entry and retrieval of the nets with the vessel stopped at the beginning and end of every haul precluded significant contamination of the samples.

2.5 Measurement of environmental factors

By means of remote-sensing devices, vessel personnel continuously recorded water temperature and salinity at 3 m during operations at selected stations throughout the study area. Whenever recording instruments became inoperable, the desired measurements were obtained by conventional methods.

3 REDUCTION OF SAMPLE MATERIAL

3.1 Treatment of collections

At the completion of a set of simultaneous hauls, members of the vessel's crew secured the nets in a vertical position and carefully washed the sample material into the respective collecting "cups". From here each collection went into a liter jar containing sufficient buffered formalin to produce a 5-percent preserving solution. After a period of settling at the laboratory, the supernatant preservative was discarded and the sample concentrate transferred to a 250-ml bottle; enough preservative was then readded to fill the bottle.

Laboratory aids trained in identification and subsampling procedures sorted all penaeid-like organisms from the numerous plankton samples. Subsampling entailed the examination and sorting of one or two 50-ml aliquots under a binocular microscope whenever an entire sample could not be scanned efficiently because of too dense a concentrate. Occasionally, when individual aliquots could not be processed for the same reason, the entire 250-ml concentrates were diluted to twice (rarely three times) their original volumes. Subsequent statistical tests showed that subsampling variation, regardless of concentrate dilution, was negligible. All penaeid-like organisms from a sample concentrate or an aliquot thereof were stored in a vial for later identification and enumeration.

3.2 Identification and enumeration of Penaeids

A serious problem in the final stages of sample reduction confronted us during the early part of the study. At that time, there existed little information that aided in the identification of larval and postlarval Penaeidae, represented locally by 5 genera and 12 or so species, all of which on cursory examination appear exactly alike at

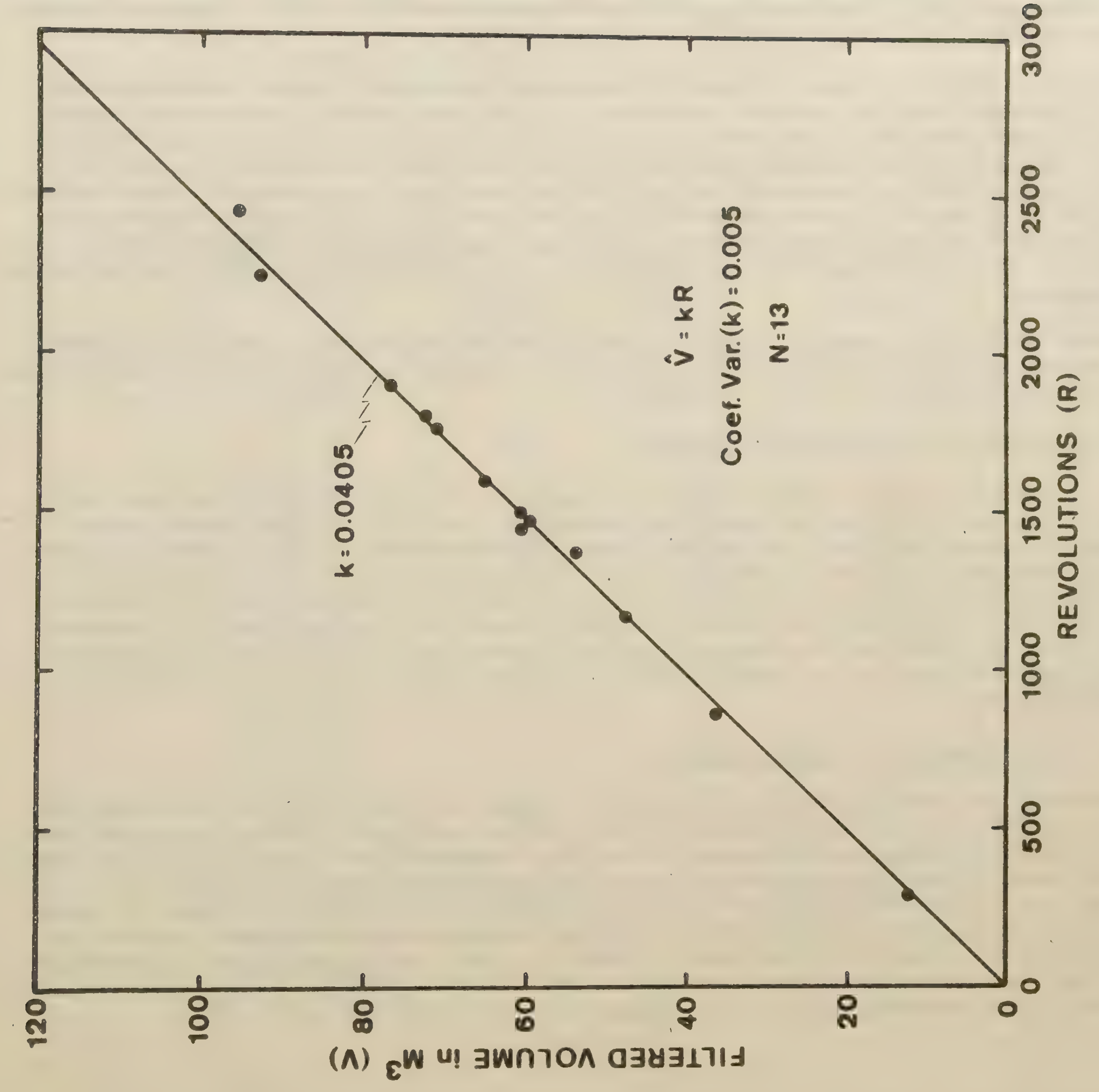

Fig. 3 Typical plot of calibration data for flowmeter used in Gulf-V plankton nets.

corresponding stages of early development. Consequently we had to employ coding systems by which to classify sample components until positive identification could be made. Since 1960, however, a considerable amount of comparative study has resulted in descriptions and keys which facilitate identifying to genus and, in some cases to species, littoral penaeids collected from the Gulf as protozoeae, myses, and postlarvae (Dobkin, 1961; Renfro and Cook, 1963; Cook, 1966; and Cook and Murphy, 1965). Positive identification of eggs and nauplii is still not practicable.

To the extent that this information permitted, we satisfactorily identified the sampled penaeids with one notable exception: It was not possible to separate larval and early postlarval brown and white shrimp, the predominant and commercially most valuable species in the northwestern Gulf.[2] We therefore combined them under the heading Penaeus and, as necessary in interpreting the data, distinguished between them on the basis of their expected seasonal distributions. In addition, the collections yielded members of three other genera - Sicyonia, Trachypenaeus, and Xiphopenaeus - but, except when evaluating the sampling scheme, all subsequent discussion deals solely with Penaeus.

After sorting to genus (or species) and stage of development, subsample elements were counted and the resulting totals adjusted to numbers per 100 m^3 by the calibration factors described earlier.

4 DISTRIBUTION OF PREJUVENILE Penaeus

We had hoped at the study's outset to sample at the offshore stations with sufficient frequency to trace the day-to-day movement of broods of young shrimp toward and into Galveston Entrance, but quickly found it impractical to do so because of manpower limitations. Instead of sampling in the Gulf once every 3 days as originally scheduled, we restricted our runs to once every 9 days, and thereby had to forgo information on rate of inshore movement. We did obtain some indication of the seasonal distribution of larval and postlarval Penaeus by area, depth, and stage of development, however, and also made a few observations on the diel distribution of postlarvae in Galveston Entrance.

4.1 Distribution by area and depth

Although the study's sampling coverage in space and time might be considered impressive by ordinary standards (Table I), the lack of positive results materially hampered statistical analysis. The results we did obtain confirmed what many others have observed, namely, that Penaeus shrimp larvae and postlarvae, while at times very abundant, are nevertheless rather elusive organisms with a distinct tendency to aggregate. That contagion is perhaps the most notable characteristic of their population distributions is attested by the data in Table II. As a consequence, the standardized counts (or their means) have been treated in the following analysis as Poisson variates and transformed accordingly by the function

$$\sqrt{x + 3/8}$$

as suggested by Rao (1952). Analysis was facilitated further by grouping the data by seasons (spring - March, April and May; summer - June through August; etc.).

To test for differences between mean sample counts from different levels of the same source of variation, we employed with the data from our offshore sampling an analysis of variance of transformed counts arranged in a 4x4x4x2 factorial design;

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[2] Some larvae and postlarvae of pink shrimp, the other local Penaeus, may have been included but this likelihood is considered small because adults and juveniles are infrequently observed in the Galveston area.

TABLE II

Distribution of prejuvenile *Penaeus* among 2,720 plankton samples collected with Gulf-V nets in the vicinity of Galveston, Texas, March 1959 - March 1960

Organisms per 100 m^3 per sample	Subdivision		
	Galveston Entrance	Gulf of Mexico	Combined
Number	Number		
0- 9	1,282	1,163	2,445
10- 19	68	44	112
20- 29	37	17	54
30- 39	23	4	27
40- 49	19	2	21
50- 59	13	4	17
60- 69	2	2	4
70- 79	5	1	6
80- 89	7	1	8
90- 99	2	0	2
100-109	1	1	2
110-119	2	0	2
120-129	2	0	2
130-139	0	0	0
140-149	2	0	2
≥150	11	5	16
Total	1,476	1,244	2,720
Zero entries	1,129	1,020	2,149

i.e., with sample counts obtained throughout 4 mo, from four areal sectors, at four distances from the survey's focus, and at two depths. Seasonal effects were assumed to be fixed. Difficulties in computation arising from unequal subclass size, caused by failure to collect a small number of samples during bad weather in March 1959 and March 1960, were precluded by adjusting the affected counts to the base subclass size of 10 samples and reducing the error degrees of freedom accordingly.

The resulting analysis suggested that, on the average, the distribution of prejuvenile Penaeus approaching Galveston Entrance was nearly homogeneous (Table III). Most noteworthy biologically was the significant seasons X sectors interaction, which indicated marked variation in mean numbers of prejuvenile Penaeus among areal sectors within each season. This seasonal change in horizontal distribution is shown graphically in Fig. 4, where it is suggested that in the spring most larvae and postlarvae approached the Entrance from the east, whereas in the summer the preponderance approached from the south and west. There is little doubt in our minds that in the former case the species in question was predominantly brown shrimp, in the latter, white shrimp. This distributional pattern furthermore reflects what has since been noted in studies of oceanic currents over the shelf of the northwestern Gulf, namely, that during spring the net nearshore drift is to the west then gradually reverses so that by midsummer it is to the east (U.S. Fish and Wildlife Service, 1963 and 1964). The obvious inferences to be drawn from these observations are that recently hatched brown and white shrimp utilizing the Galveston estuary as a nursery area generally originate on spawning grounds lying to the east and to the west, respectively.

In a similar manner we examined the distribution of young Penaeus - practically all postlarvae - in Galveston Entrance. This analysis (Table IV), which also assumed temporal effects to be fixed, tested the hypotheses of no differences between mean standardized counts from each of two depths, in two areas (V and VI in Fig. 1), during 12 mo. Expected variation among units of time was again statistically significant but, in contrast to results of the preceding analysis, the outstanding sources of variation were depths and the depths X months interaction. More individuals on the average at the lower depth is interpreted to mean an increasing adaptation to the benthic existence of older shrimp as the rapidly developing postlarvae approach and transit tidal passes such as Galveston Entrance. Of even greater interest was a change with time in their depth distribution, which appeared to be species-associated. During early spring (March-April), when the influx of brown shrimp postlarvae reaches its peak (Baxter, 1963), postlarval density was greatest at the 6-m depth. In early summer (June-July) when the immigration of white shrimp postlarvae is maximal, postlarvae were most abundant at the 1/2-m level. This observation may reflect a difference in the behavior, hence distribution, of postlarval white shrimp that makes estimation of their abundance when passing through Galveston Entrance much more difficult than in the case of brown shrimp postlarvae.

An attempt is made in Fig. 5 to portray the seasonal abundance of postlarval Penaeus as they move through Galveston Entrance. Unfortunately, our inability to separate the brown and white species resulted in the distribution of each being masked. The plotted data nevertheless tend to agree with those developed by Baxter (1963) in the years immediately following this study. Otherwise we are unable to offer an explanation - other than to point to vagaries of sampling - of why the fairly strong evidence of abundant larval and postlarval (white) shrimp offshore during the summer (Fig. 4) was not paralleled by corresponding evidence of postlarval abundance in Galveston Entrance (Fig. 5).

4.2 Distribution by developmental stage

Of more than passing interest in the search for answers to where, when, and how intensively the shrimps of commercial importance spawn is knowledge of the distribution of their early life history stages. It follows that delineating concentrations of the very young and transitory nauplial, protozoeal, and mysis stages is tantamount to locating the parent shrimps' spawning grounds. To facilitate their examination for this

TABLE III

Analysis of variance of transformed Penaeus counts from the Gulf of Mexico off Galveston, Texas, March 1959 - March 1960. /Basic data are total prejuvenile Penaeus per 100 m^3 in 10 samples each at two depths, at four distances (tiers) and in four areal sectors established radially from Galveston Entrance, and during four seasons./

Source of variation	D.f.	Sum of squares	Mean square
Seasons	3	600.73	200.24**
Sectors	3	27.67	9.22
Tiers	3	27.32	9.11
Depths	1	12.49	12.49
Sectors x Tiers	9	53.54	5.95
Sectors x Depths	3	26.17	8.72
Tiers x Depths	3	27.74	9.25
Sectors x Tiers x Depths	9	26.68	2.96
Error	77	853.53	11.08
Seasons x Sectors	(9)	(257.67)	(28.63)**
Seasons x Tiers	(9)	(191.07)	(21.23)
Seasons x Depths	(3)	(48.17)	(16.06)
Residual	(56)	(356.62)	(6.37)
Total	111	1,655.87	

** Significant at 1 percent level

TABLE IV

Analysis of variance of transformed Penaeus counts from Galveston Entrance, Texas, March 1959 - March 1960. /Basic data are average numbers of prejuvenile Penaeus per 100 m^3 in 1,476 samples collected systematically as shown in Table I./

Source of variation	D.f.	Sum of squares	Mean square
Months	11	97.49	8.86**
Subareas/Months	12	10.75	0.89
Depths	1	3.93	3.93*
Depths x Months	11	34.88	3.17**
Depths x Months/Subareas	12	5.23	0.44
Total	47	152.28	

** Significant at 1 percent level
* Significant at 5 percent level

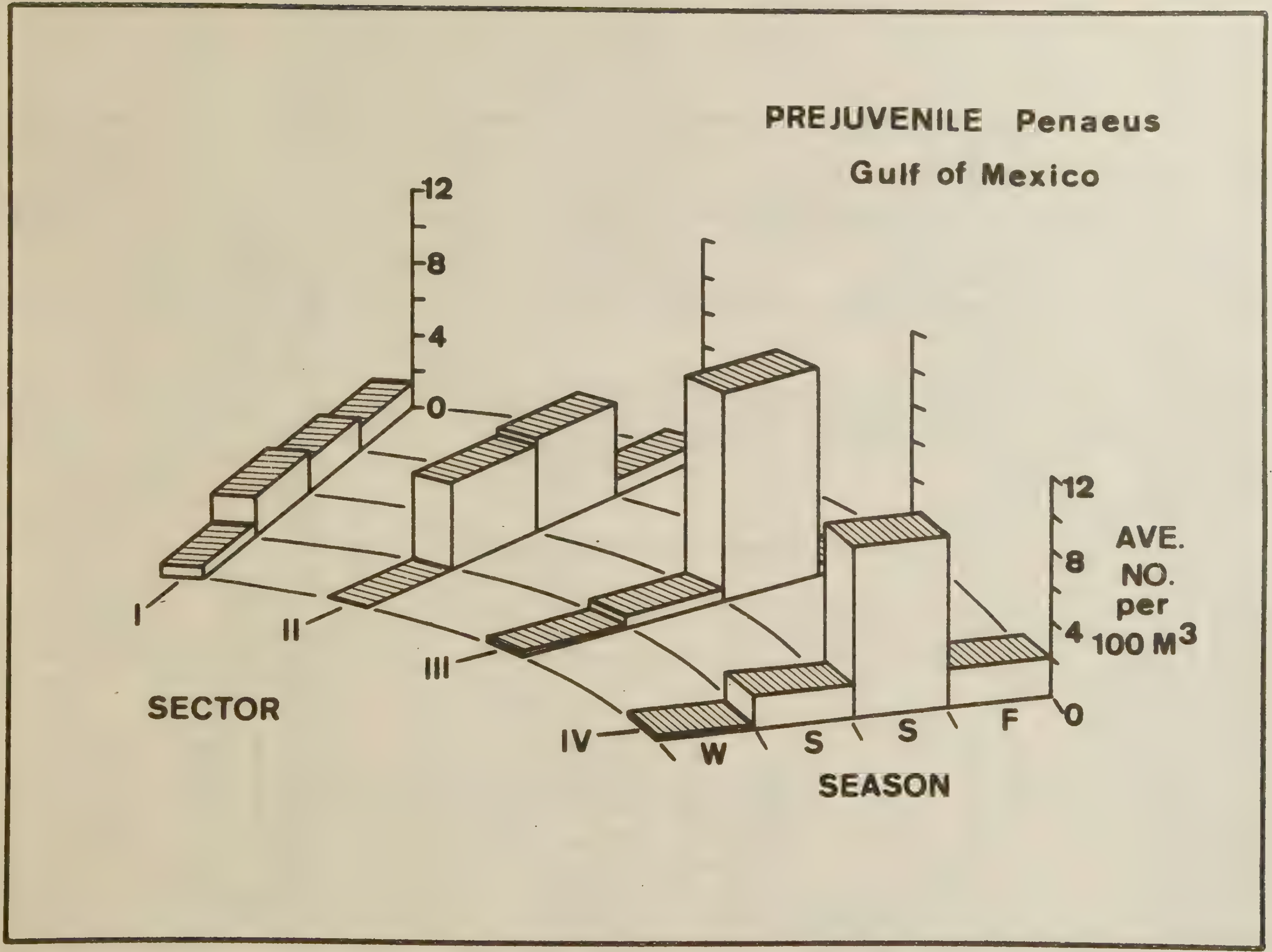

Fig. 4 The distribution of prejuvenile Penaeus by season and areal sector in the Gulf of Mexico off Galveston, Texas, March 1959 - March 1960.

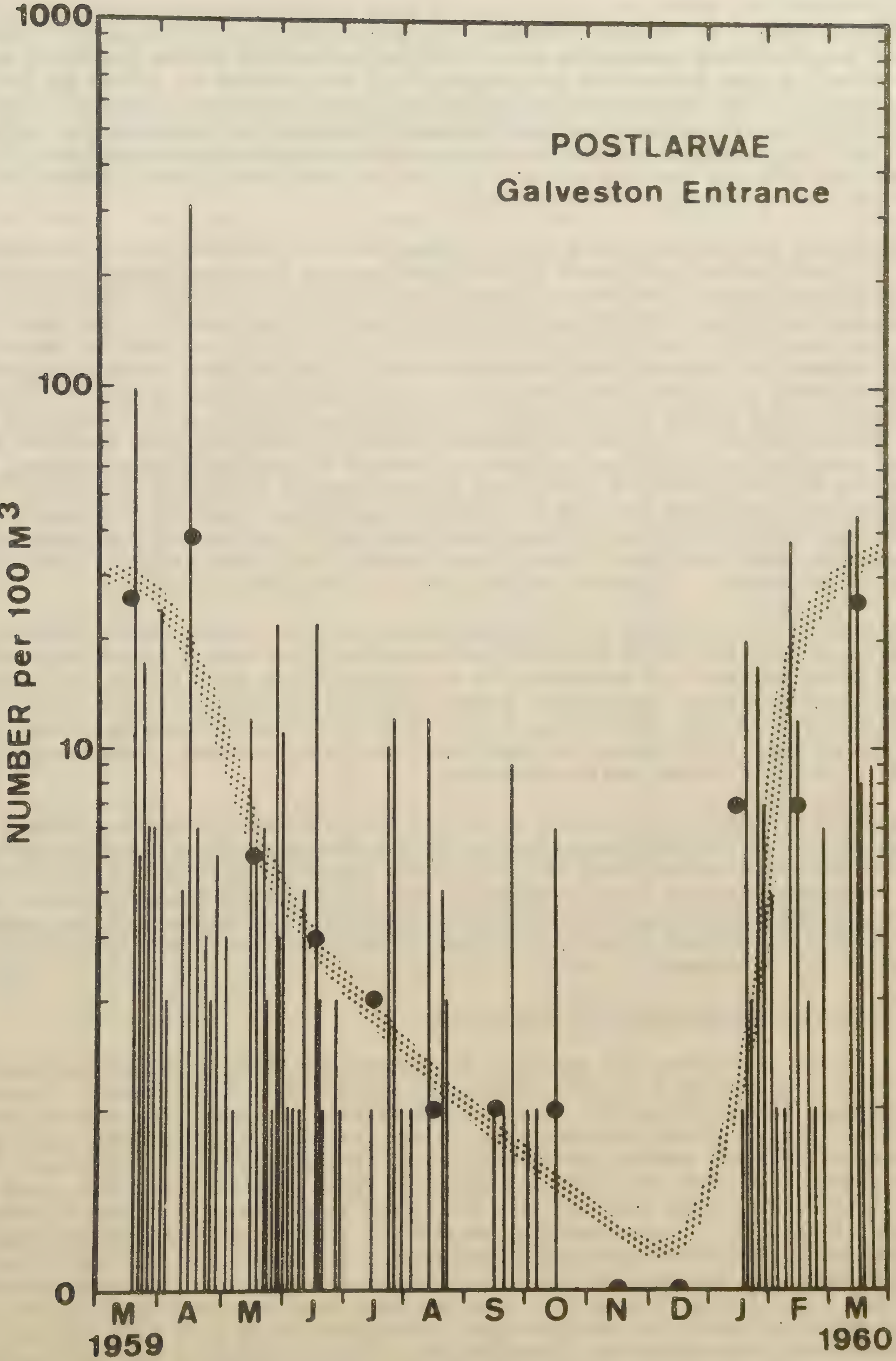

Fig. 5 Average density of postlarval Penaeus in Galveston Entrance, Texas, March 1959 – March 1960. [Shaded circles represent monthly mean numbers per 100 m^3.]

purpose we reduced the pertinent study data to mean standardized counts of each developmental stage according to season, distance from shore, and depth (Table V). Major features of the resulting tabulation are: (1) the paucity of larvae (nauplii, protozoeae, and myses) during the autumn and winter; (2) the absence of larvae at the bottom in all seasons; (3) the absence of larvae in the upper layer and in waters closer than 10 km from shore during spring when peak shoreward movement of brown shrimp larvae is expected; (4) the relatively great abundance of all stages at mid-depths and all distances from shore during the summer; and (5) the comparatively lower numbers of postlarvae on the bottom during most of the year.

Particularly interesting, in view of a prevalent theory postulating mass overwintering of brown shrimp postlarvae in nearshore waters (Kutkuhn, 1962; Temple and Fischer, 1968; and Aldrich, Wood and Baxter, 1968), was the complete absence of *Penaeus* postlarvae in our (52) bottom samples throughout the winter. One might question here the possibility that differential efficiency of the gear used to sample on the bottom biassed our results, but re-examination of the raw data showed that early and late postlarvae of related penaeids entered bottom collections just as frequently in the winter as they did in other seasons when *Penaeus* postlarvae were commonly encountered at the bottom. On 8 and 22 December 1959, for example, four and five bottom (8 to 16 m) samples, respectively, yielded an average of two *Xiphopenaeus krøyeri* postlarvae per 100 m^3; on 20 January 1960, four bottom samples contained an average of 10 *Trachypenaeus* spp. postlarvae per 100 m^3. These observations lead us to discount gear selectivity as a possible source of data bias, and simply add to the confusion arising from speculation about the fate of young brown shrimp that hatch in the autumn but do not appear in estuaries in expected numbers during autumn and winter.

We believe it safe to say, as in the preceding analysis, that these observations largely mirror events involving two different species. The spring counts most likely represented brown shrimp that originated on spawning grounds well beyond the seaward boundary of the study area, whereas the summer counts largely represented white shrimp whose spawning grounds were situated much closer to and possibly overlapped the study area. If one accepts this view ss a cogent one, the distributional patterns manifested by the data in Table V become self-explanatory.

Examination of comparably treated data from the Entrance collections (Table VI) confirms in large measure what was suggested by the data in Table V, namely, the absence of larvae in nearshore waters (0-10 km) during the autumn, winter and spring; the tendency for postlarval density to be greatest at mid-depth during the late winter and spring when the influx of young brown shrimp is maximal; and, because of the occurrence of larvae close to shore and in the tidal pass during the summer, the spawning of white shrimp not too far offshore.

4.3 Distribution according to time of day

With a single exception, all sampling throughout the study area was performed in daylight, on the assumption that diel changes in the vertical displacement of prejuvenile *Penaeus*, if they occurred, remained essentially the same from sampling date to sampling date. The exception occurred in late May, within a 24-h interval during which large numbers of (white?) shrimp postlarvae passed through Galveston Entrance. In that period and location we made two identical sampling runs, both on flood tide, one in bright daylight between 0900 and 1100 CST, the other in darkness 17 h later between 0400 and 0600 CST (Table VII). Unfortunately, we did not repeat this exercise and therefore make no claim as to the conclusiveness of the data. But their analysis did allay some fear that our sampling was possibly not as efficient as it should have been because it routinely took place during that part of the day when many believed the upper 6 to 8 m of water is generally devoid of the organisms whose density we were attempting to measure. Even more convincing was a comparison of data obtained in the Gulf on 166 sampling dates when collections were taken simultaneously at three depths - 1½ m, 6 m, and on the bottom (Table VIII). We believe these data dispel any serious doubt that failure to sample in darkness as well as in daylight, i.e., to consider light intensity

TABLE V

Distribution of prejuvenile *Penaeus* in the Gulf of
Mexico off Galveston, Texas, March 1959 - March 1960.
[Data are coded average numbers of organisms per 100 m^3.]

Season	Distance from shore	Distribution of samples			Developmental stage and depth of collections								
					Nauplii**		Protozoeae		Myses		Postlarvae		
		1½ m	6 m	Bottom*	1½ m	6 m	1½ m	6 m	1½ m	6 m	1½ m	6 m	Bottom
	Km	Number					Number x 10						
Winter	0-10	90	90	36	0	0	0	0	0	0	2	4	0
	10-20	27	27	0	0	0	0	0	0	0	2	1	-
	20-40	27	27	16	0	0	0	0	0	0	0	0	0
Spring	0-10	90	90	21	0	0	0	0	0	0	21	32	93
	10-20	25	25	3	0	0	0	12	0	7	0	10	0
	20-40	27	27	13	0	0	0	4	0	4	10	64	0
Summer	0-10	100	100	10	3	39	0	0	1	0	33	25	6
	10-20	30	30	3	0	10	21	4	7	3	36	63	0
	20-40	30	30	3	0	43	0	34	66	16	74	48	0
Autumn	0-10	110	110	39	0	0	0	0	0	0	22	7	3
	10-20	33	33	1	0	2	0	0	0	0	15	16	0
	20-40	33	33	21	0	0	0	0	0	0	0	0	0
Combined	0-40	622	622	166	1	9	1	2	4	1	19	20	13

* Depth 7 to 12 m at the 12 stations within 10 km of shore
" 15 m " " 2 " " 20 km " "
" 15 to 16 m " " 2 " " 40 km " "

** Provisional identification

TABLE VI

Distribution of prejuvenile Penaeus in Galveston Entrance, Texas, March 1959 - March 1960. [Data are coded average numbers of organisms per 100 m^3.]

Season	Distribution of samples			Developmental stage and depth of collections					
				Protozoeas and myses			Postlarvae		
	1½ m	6 m	Bottom	1½ m	6 m	Bottom	1½ m	6 m	Bottom
	Number			Number x 10					
Winter	148	148	25	0	0	0	37	44	18
Spring	236	266	55	0	0	0	110	314	34
Summer	192	198	16	0	<1	0	27	16	45
Autumn	144	144	22	0	0	0	9	6	13
Combined	720	756	118	0	<1	0	53	124	28

TABLE VII

Comparison by depth and time of day of average numbers of Penaeus postlarvae collected in Galveston Entrance, Texas, 25-26 May, 1960. [Number of collections in parentheses]

Sampling condition	Depth			Combined
	1½ m	6 m	Bottom*	
Daylight (0900-1100)	12 (8)	31 (8)	0 (4)	17 (20)
Darkness (0400-0600)	4 (8)	1 (8)	12 (4)	5 (20)
Combined	8(16)	16(16)	6 (8)	11 (40)

* Depth 7½ to 10 m

as a variable significantly influencing vertical distribution of planktonic-stage Penaeus, materially biassed the study's results; sampling concurrently at 1½ and 6 m was evidently enough to account for variation due to diel differences in depth distribution. Possible bias due to differential catchability of the two types of gear was also considered negligible, the rationale being that the No. 1 mesh over the codend of the trawl was small enough (420 µ) to retain the smallest larva we expected to encounter. Although Temple and Fischer (1965) demonstrated changes with time of day in the stratification of planktonic penaeids, their data are not directly comparable to ours because they combined representatives of three other genera with those of Penaeus.

More recent work still leaves unsettled, however, the question of diel changes in the distribution of postlarval Penaeus entering Galveston Bay. Whereas standardized sampling every 2 h for 4 days in Galveston Entrance (April 1963) yielded, on the average, almost twice as many postlarval brown shrimp during darkness as in daylight (U.S. Fish and Wildlife Service, 1964), a similar study in Rollover Pass (March and April 1965) indicated no relation between sampling success and time of day (U.S. Fish and Wildlife Service, 1966).

4.4 Role of environmental factors

Graphical comparison failed to reveal any apparent relation between the distributions of prejuvenile Penaeus and those of temperature or salinity. Average subsurface (3 m) temperatures closely paralleled corresponding Entrance temperatures (Fig. 6) and the only inference we feel justified in drawing at this time is that generally low winter temperatures effectively slowed postlarval movement into and through Galveston Entrance (see Fig. 5 and 6). Otherwise the data suggest nothing more than that salinity in the Entrance did not materially influence the movement of postlarvae into the bay.

TABLE VIII

Distribution of Penaeus larvae and postlarvae at three depths in the Gulf of Mexico off Galveston, Texas, March 1959 - March 1960. [Data are total numbers or organisms per 100 m^3 in 498 samples, one collected simultaneously at each depth during 166 samplings. These samplings were about evenly spread over the study year and all took place in daylight. Average depth at a all stations in the study area was 14 m; maximum depth at any station was 17 m.]

Developmental stage	Depth		
	1½ m	6 m	Bottom
		Number	
Larvae*	63	270	0
Postlarvae	234	197	213
All	297	467	213

* Includes nauplii, protozoeae, and myses

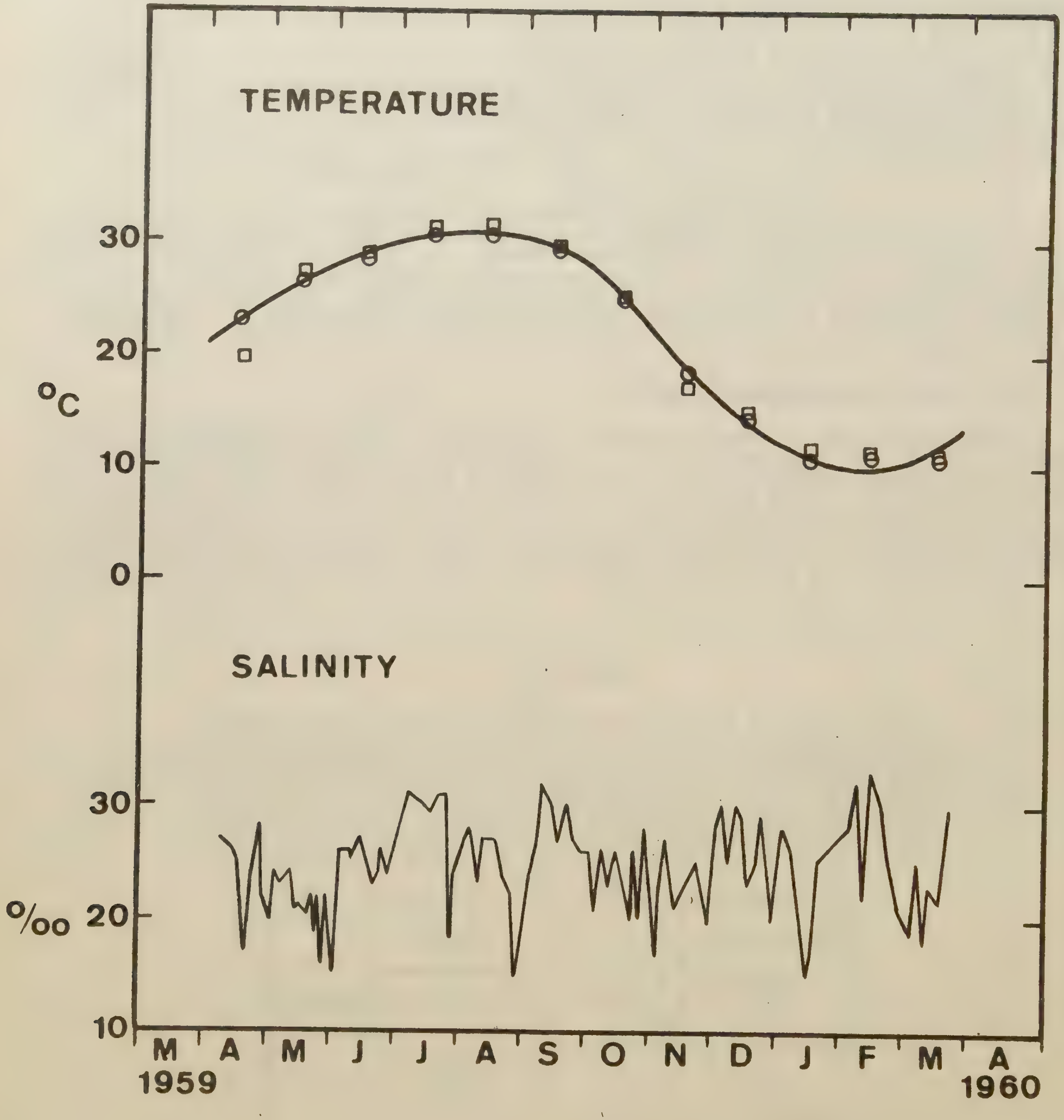

Fig. 6 Monthly average water temperature in Galveston Entrance, Texas (O), and the nearby Gulf of Mexico (□), and salinity in Galveston Entrance, March 1959 - March 1960.

5 COMPUTATION OF DENSITY

Point estimation of the overall abundance of prejuvenile Penaeus as a possible indication of spawning success was not a major objective of this study. Understandably, it would have been meaningless to present such estimates without comparative data from previous years, or good prospects for their continued acquisition in the future. But we had designed the sampling scheme with the additional purpose of density estimation in mind, and feel its statistical appraisal in this light is appropriate here.

Evaluation involved an analysis-of-variance model developed for the treatment of data collected by multistage, or nested, sampling techniques such as the one we employed (Anderson and Bancroft, 1952, p. 325). To simplify computations we selected those sets of data - each set representing a sampling day - that contained the least number of missing entries and in which the number of concentrate aliquots was uniformly two. In addition to counts of prejuvenile Penaeus, we also included in this analysis the standardized counts of all other penaeid larvae and postlarvae (Sicyonia, Trachypenaeus, and Xiphopenaeus) entering the aliquots. The sources of variation treated in our appraisal of the offshore sampling scheme were: collection dates (4), radiating transects (4), stations along each transect (4), depths at each station (2), and aliquots (subsamples) from the single collection at each depth (2). In the Entrance survey, the sources were: collection dates (8), subareas (2), stations in each subarea (4), depths at each station (2), and aliquots from the single collection at each depth (2). In both offshore and inshore surveys the number of sampling dates constituted a small fraction of all possible dates and, accordingly, the sampling rates in the remaining subclasses were small. Because the analysis entailed no probability statements, transformation of the Poisson aliquot counts (number per 10 m^3) was unnecessary.

The resulting analysis for the offshore sampling scheme (Table IXA) disclosed that, aside from the large expected variability among dates, the major source of variation was between depths. Without increasing the overall sampling rate, survey efficiency could have been improved 15 percent by doubling the number of transects and halving the number of stations on each, and an additional 7 percent by also doubling the number of depths and halving the number of aliquots (Table IXB). Similarly, the sampling rate could have been reduced a significant 25 percent with a loss in efficiency of only 3 percent had the number of stations been reduced to two per transect, the number of depths (or samples) at each station increased to six, and the number of aliquots reduced to one.

The corresponding analysis for the study's inshore survey identified areas, stations, and depths (apart from dates) as roughly equivalent sources of variation (Table X). Computation of predicted variances for different combinations of survey variables, showed that no change in the initial procedure would have led to more efficient sampling, or to a reduced sampling rate with the same level of efficiency. Hence the reduction in stations in subarea V from four to two early in the study did contribute to a slight decrease in sampling efficiency.

In the assessment of both offshore and inshore surveys, variation between aliquots proved negligible. Thus, counts from a single aliquot would have sufficed during routine examination of sample concentrates. Actually, only 4 percent of the 3,004 samples examined during the study were so treated; 60 percent were processed by making counts in two aliquots and the remaining 36 percent by examining the entire concentrate.

The foregoing analyses demonstrate the high degree of variability with time in the density of prejuvenile penaeids. The relatively high coefficients of variation associated with the estimated mean numbers of larvae and postlarvae per unit volume (Tables IXA and X) could have been reduced significantly only by more frequent sampling. We believe that while control of spatial variation is essential in surveying for the abundance of prejuvenile Penaeus, future work should consider more frequent sampling than was scheduled in this study if the reliability of density estimates is to be increased to more acceptable levels.

TABLE IX

Appraisal of scheme to sample for density of prejuvenile penaeids in Gulf of Mexico off Galveston, Texas, March 1959 - March 1960. A: Analysis of variance of selected sampling data (number of organisms per 10 m^3). B: Percent increase in sampling efficiency based on predicted variances of mean density using indicated combinations of sampling variables

A

Source of variation	D.f.	Sum of squares	Mean square	Estimated variance component
Dates	3	289.23	96.41	$s^2_{Dt} = 0.70$
Transects/Dates	12	616.55	51.38	$s^2_T = 1.76$
Stations/Transects	48	1,115.56	23.24	$s^2_{St} = 1.85$
Depths/Stations	64	1,015.25	15.86	$s^2_D = 7.03$
Subsamples/Depths	128	231.50	1.81	$s^2_{SS} = 1.81$
Total	255	3,268.09		

$\bar{x} = 1.68$ / 10 m^3

$$s^2_{(\bar{x})} = \frac{s^2_{Dt}}{4} + \frac{s^2_T}{16} + \frac{s^2_{St}}{64} + \frac{s^2_D}{128} + \frac{s^2_{SS}}{256} = 0.38$$

Coef. Var. $(\bar{x})$ = 0.36

B

Stations		2			4			8		
Depths		2	4	6	2	4	6	2	4	6
Transects	Subsamples									
2	1	-109	-72	-60	-57	-38	-32	-31	-22	-19
	2	-101	-68	-58	-53	-37	-31	-29	-21	-18
	3	-99	-67	-56	-52	-36	-31	-28	-20	-18
	All	-94	-65	-55	-49	-35	-30	-27	-20	-18
4	1	-28	-9	-3	-2	7	10	11	16	17
	2	-24	-7	-2	0	8	11	12	16	18
	3	-23	-7	-2	1	9	11	12	16	18
	All	-20	-6	-1	2	9	12	13	17	18
8	1	13	22	25	26	30	32	32	34	35
	2	15	23	26	27	31	32	33	35	36
	3	15	23	26	27	31	32	33	35	36
	All	16	24	26	28	31	33	33	35	36

TABLE X

Appraisal of scheme to sample for density of prejuvenile penaeids in Galveston Entrance, Texas, March 1959 - March 1960: Analysis of variance of selected sampling data (number of organisms per 10 m^3).

Source of variation	D.f.	Sum of squares	Mean square	Estimated variance component
Dates	7	117.94	16.85	$s^2_{Dt} = 0.39$
Subareas/Dates	8	33.75	4.22	$s^2_{SA} = 0.05$
Stations/Subareas	48	163.00	3.40	$s^2_{St} = 0.04$
Depths/Stations	64	227.75	3.56	$s^2_{D} = 1.29$
Subsamples/Depths	128	126.00	0.98	$s^2_{SS} = 0.98$
Total	255	668.44		

$\bar{X} = 0.83 / 10\ m^3$

$$s^2_{(\bar{x})} = \frac{s^2_{Dt}}{8} + \frac{s^2_{SA}}{16} + \frac{s^2_{St}}{64} + \frac{s^2_{D}}{128} + \frac{s^2_{SS}}{256} = 0.07$$

Coef. Var. $(\bar{x}) = 0.31$

6 SUMMARY

In early 1959 the Bureau of Commercial Fisheries began a study to determine when, from what direction, at what stage of development, how many, and under what conditions, prejuvenile shrimp of the economically important genus Penaeus enter the extensive Galveston (Texas) estuary. The study's findings, together with the results of subsequent work, were to aid in circumscribing offshore spawning areas and provide information on the extent to which the progeny of shrimp reproducing in each area are nurtured in each estuary bordering the northern Gulf of Mexico.

The study area consisted of two subdivisions, the Entrance itself and about 1,500 km^2 of the adjoining Gulf. Sampling for the planktonic-stage Penaeus proceeded synoptically in both areas with Gulf-V plankton nets and intermittently with a small trawl. The sampling scheme permitted assessment of variations in the young shrimps' horizontal, vertical, and temporal distribution. Limited resources precluded control of variation due to such factors as time of day, stage of tide, and quality of environment.

Over 3,000 collections obtained during 53 wk of sampling - one biological year - yielded the data on which the study was based. The more significant results of their analysis may be summarized as follows:

(1) Despite a comparatively high sampling frequency, once every 9 days in the nearby Gulf and once every 3 days in Galveston Entrance, the temporal distribution of collections was insufficient to trace the fairly rapid movement of newly hatched broods of shrimp from offshore spawning grounds into the important Galveston Bay nursery area.

(2) The data revealed, however, that horizontal distribution of Penaeus larvae and postlarvae in the Gulf, and vertical distribution of Penaeus postlarvae in the Entrance, changed markedly with the seasons. During the summer, most prejuvenile Penaeus approached the Entrance from the south and west, whereas in the late winter and early spring, most young shrimp moved in from the east. Postlarvae moving through the Entrance in summer distributed themselves more uniformly in the water column than did those passing through in spring when greater numbers were encountered in the lower strata.

(3) Except during the summer few Penaeus larvae entered collections within 10 km of shore. Identifying each species on the basis of its expected spawning time (re Item (2) above), we further inferred that white shrimp generally spawn in shallower water than do brown shrimp.

(4) Failure of the sampling scheme to account for possibly significant variation in the distribution of prejuvenile shrimp with time of day did not seriously bias the study's findings.

(5) Penaeus larvae were never detected in collections from the bottom; rarely did postlarvae occur in greater abundance at the bottom than at higher levels of the water column; and not once during the winter were postlarvae observed on the bottom at offshore stations.

(6) The data provided no evidence of a functional relationship between corresponding distributions of prejuvenile Penaeus and of environmental factors (specifically temperature and salinity).

(7) For estimating density of prejuvenile penaeids, the sampling scheme employed in this study was relatively inefficient to the degree that it failed to account for wide temporal variation in organism abundance. On the other hand, it incorporated adequate control of spatial variation, although slight changes in the distribution of sampling effort would have led to more reliable density estimates.

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We thank the many persons who assisted in the laborious task of sorting the several thousand plankton collections upon which this study was based. We also appreciate the numerous courtesies extended by Mr. I. Guidroz, captain-owner of the M/V JOYCE ELAINE, and Mr. J. McMurrey, captain-owner of the M/V LUCKY LADY, the vessels employed under charter during the study's first 15 and remaining 38 weeks, respectively.

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VARIATIONS IN PROTANDRIC HERMAPHRODITISM OF Pandalus borealis

by

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Abstract

The deep-sea prawn (Pandalus borealis) is a boreal species, whose European distribution extends from the Arctic Ocean to the northern North Sea. The species exhibits protandric hermaphroditism, i.e., the young are males but later became females. In the North Atlantic the prawns show great variations in growth, age and in sexual maturity. In the far north the prawns become mature females when five years old, while in the south when two and a half years old. It appears that sea temperature is the regulatory factor for growth and maturation. A year-class of prawns upon maturity may split into two fractions: one slow-growing and retaining the male sexual characteristics, and the other fast-growing and changing into females. The length frequency distribution of such a divided year-class may show two maxima.

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VARIATIONS DANS L'APPARITION DE LA PROTANDRIE CHEZ *Pandalus borealis*

Résumé

La crevette nordique (*Pandalus borealis*) est une espèce boréale dont l'aire européenne de répartition s'étend de l'océan Arctique au secteur septentrional de la mer du Nord. Il s'agit d'une espèce protandrique, c'est-à-dire que l'animal, d'abord mâle, devient ensuite femelle. Dans l'Atlantique Nord, de grandes différences apparaissent en ce qui concerne la croissance, l'âge et la maturité sexuelle des crevettes. Dans l'extrême Nord, elles deviennent femelles matures à cinq ans, alors que dans le Sud, elles le deviennent à deux ans et demi. Il semble que la température de la mer soit le facteur déterminant en matière de croissance et de maturation. Arrivee à maturité une classe de crevettes du même âge, peut se diviser en deux fractions: l'une à croissance lente et qui conserve les caractéristiques sexuelles du mâle, l'autre à croissance rapide qui se transforme en femelle. La distribution des fréquences de longueur d'une telle classe peut accuser deux maxima.

VARIACIONES DEL HERMAFRODITISMO PROTANDRICO DE *Pandalus borealis*

Extracto

El camarón *Pandalus borealis* es una especie boreal cuya distribución europea va desde el Océano Artico hasta la parte septentrional del Mar del Norte. Las especies exhiben hermafroditismo protándrico, es decir, los jóvenes son machos pero más tarde se transforman en hembras. En el norte del Atlántico varían mucho el crecimiento, edad y madurez sexual de los camarones. En el extremo septentrional *Pandalus borealis* se transforma en hembras maduras a los cinco años de edad, en tanto que en el sur ocurre el fenómeno a los dos años y medio. Parece ser que la temperatura del mar es el factor regulador del crecimiento y la maduración. El camarón de la clase de un año se divide en dos fracciones al alcanzar la madurez: una de crecimiento lento que conserva las características sexuales masculinas y la otra de crecimiento rápido que se transforma en hembra. También puede haber dos máximos en la distribución de frecuencia de tallas de una clase anual así dividida.

1 SUMMARY OF PREVIOUS OBSERVATIONS

The deep-sea prawn is a boreal species with a northern distribution. This crustacean has a life history of a very complex nature. In the nineteen thirties it was discovered to be a protandric hermaphrodite, i.e. each prawn has the ability to change its sex in such a manner that in early life it acts as a male and later it acts as a female. Early investigations further indicated that the growth and sexual maturity of the prawn were largely uniform in all areas of its distribution, as for instance on the Pacific Coast of Canada as well as in the Atlantic, where the prawn stocks off the Scandinavian countries were investigated. The general biological picture was that the deep-sea prawn functioned as an active male when 1½ years of age, at a length of 90 mm, then changed its sex and spawned as a female when 2½ years of age, at a length of 120 mm. Subsequent investigations proved, however, that the growth rate and the sexual development of the deep-sea prawn in Arctic regions was much slower than in any of the areas previously investigated. For instance, in Spitsbergen waters (Lat. 78°N) the prawns did not mature as males till 3 years of age, they remained as functional males in the fourth year and did not reach the female stage till 5 years old. It was natural to pursue the investigations on the deep-sea prawn on the hypothesis that in different latitudes from south to north we might be able to find prawn populations which by their pattern of growth and sexual development would form natural intermediate links between the prawns in the southern and northern area of distribution. Later investigations showed that the cycle of growth and maturity in the deep-sea prawn varied not only from one locality to another, but also from brood to brood born in different years in one and the same locality, which indicated the basic rules for the reaction of the prawns toward changes in the environment.

2 FACTORS AFFECTING MATURITY, SEX CHANGE AND SPAWNING

Decreasing temperatures in the sea will cause slower growth and retard maturing in the deep-sea prawn. This means that in the North Atlantic we will generally find more slow-growing and slow-maturing prawns the farther north we go. In Norway many prawn fields are situated in socalled "threshold fjords", i.e. deep inlets with a shallow barrier at the entrance. In these fjords we often find lower temperatures and salinities than in the open sea outside. The prawns in these threshold fjords can, without regard to geographic latitude, show a life history approaching that of the slow-growing prawns in Arctic waters.

The spawning of the deep-sea prawn also shows features which seem to conform to a certain pattern. In the southern part of the area of distribution spawning is in October-November, the females carrying their eggs about 5 months till they hatch in the following March-April. However, in the extreme north (Lat. 78°N) spawning takes place 3 months earlier than in the south, and the eggs hatch 2 months later the following spring, the ovigerous period in the Arctic thus lasting for about 9 months. Along the coast of Norway we find intermediate duration of the ovigerous period, 7 to 8 months in northern Norway decreasing to 5 months further south. The general rule seems to be that the colder the environment, the earlier spawning and the longer the ovigerous period.

2.1 Effects of age and size

Generally all individuals of a prawn population in the southern area of distribution spawn as active males at a length of about 90 mm and age 1½ years, and as active females at a length of about 120 mm and age 2½ years. But going progressively northwards the prawns mature as males and females respectively much later in life. In spite of the great difference in age when maturing, the size of males and females respectively is largely the same when spawning. There is obviously an intimate connection between sexual maturity and rate of growth in the different areas. The basic principle seems to be that a particular prawn population, or a single year-class, having a high rate of growth produces sexually mature males and females earlier in life than does a slow-growing population. The number of individuals within an age-group maturing as respectively males and females is determined not so much by the age as by the size attained by the individual prawns. This is illustrated in Fig. 1.

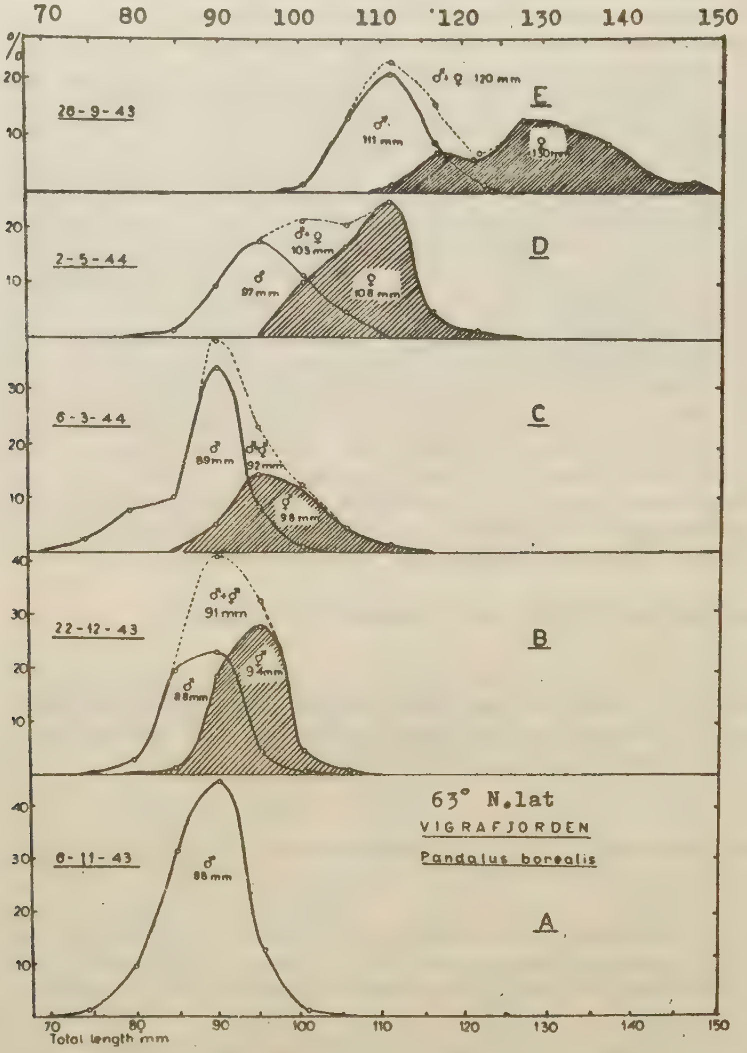

Fig. 1 Group of male prawns (A), the separation of a female fraction (B), and the subsequent growth of both fractions (C.D.E.). (E relates to the previous year-group to that shown in A to D).

A year-class of prawns 1½ years old may show a size distribution as shown in Fig. 1 A, containing prawns 75 to 100 mm in length with a mean length of 88 mm. This size-group of prawns contains active males in late autumn. In Fig. 1 B a division of the age-group has just taken place, one part having attained transitional characters into females, the other part retaining the male characters. The division of the age-group does not occur at a sharply defined size. The male and the transitional fractions form two separate groups which overlap in size. During the subsequent months the two fractions show a steadily increasing difference in mean size caused by the difference in rate of growth (Fig. 1, C,D,E,). In the absence of information on the late growth of this year-group, Fig. 1 E has been compiled from data for the previous year.

The principle governing the mechanism of this division within an age-group seems to be that the largest individuals of the group will change into females, while the smaller prawns remain males. The very smallest individuals of an age-group may even form a third fraction on the extreme left consisting of immature prawns. The division of an age-group into different sex categories is closely connected with the attainment of a more or less definite size level. If for instance an age-group has attained a mean size of about 80 mm in autumn only a few individuals will mature as females. If, however, the mean size attained by the age-group is 100 to 110 mm perhaps 25 to 75 per-cent become females. Age-groups of a mean size of 120 mm in autumn will generally consist of females only. The lengths stated only indicate the trend of the sexual development.

The general rule seems to be that the largest males of an age-group undergo the transformation into females first. The growth of the transition animals in the following months is accelerated, while those animals which remain males have a restricted growth. As a natural consequence, a single age-group of prawns may come to consist of two distinct size-groups, one of small males and the other of large females; such an example is illustrated in Fig. 1 E. If not closely followed they would normally have been misinterpreted as two different age-groups.

2.2 Effects of latitude and temperature

Environment, rate of growth, and sexual maturing are closely connected factors which find their expression in the varied life histories of Pandalus borealis in the many localities between the Arctic Ocean and more southern areas. The prawn can sustain life and multiply within a wide range of temperatures, submitting to local conditions, growing and maturing in conformity to laws laid down by nature. In temperate surroundings the deep-sea prawm grows fast and matures early, in the cold waters of the far north the prawn grows slowly and matures late in life, while in between we find prawn populations which in their life history show intermediate links between the two extremes. Examples of this extreme pattern of variation is shown in Fig. 2. From one growth type to another we find a natural transition expressed by a varied sexual division within the different age-groups.

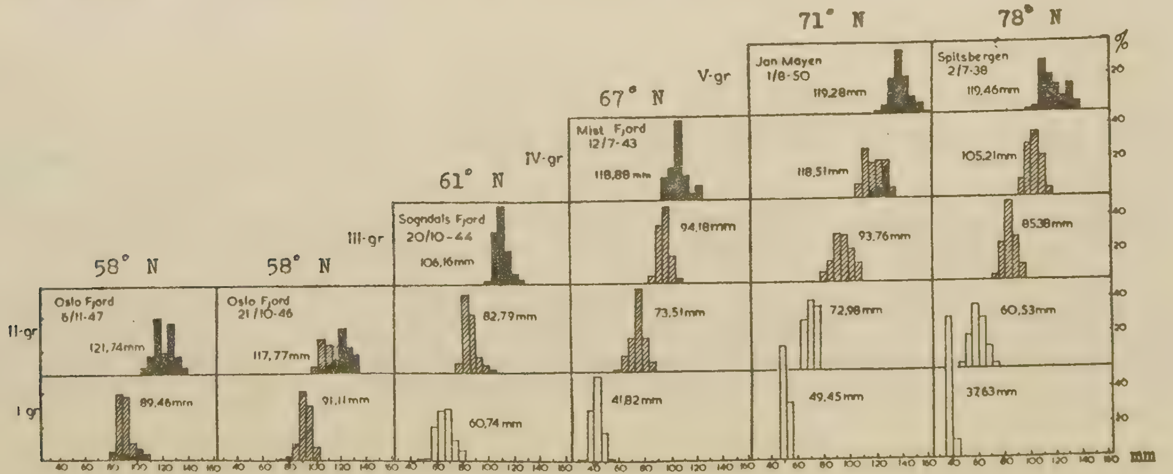

Fig. 2 The variations in age, size, and sexual development of the deep-sea prawn in various localities along the Norwegian coast and in Arctic waters. White: young. Shaded: males. Black: females.

3 GROWTH RATE AND PRODUCTIVITY

The variations in growth and maturity of the deep-sea prawn will naturally influence the productivity and the renewal of the prawn stocks on the different fishing grounds, and thus also have a certain effect on the commercial prawn fishery. In localities where P. borealis has a slow rate of growth the prawns become ovigerous late in life and produce generally only one brood, while in localities where the rate of growth is fast two generations may breed within the same period of time. If a prawn field with a high reproductive ability should be overfished the stock would recuperate in a short space of time, while a locality with a low reproductive rate would need a longer time to become remunerative again.

The practical results of the investigations on the deep-sea prawn indicate that certain prawn fields, particularly in Arctic waters, are unlikely to stand the same fishing intensity as those in southern areas. These biological aspects must be taken into consideration when protective measures are contemplated.

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NOTAS BIOLOGICO-PESQUERAS SOBRE CAMARON BLANCO *Penaeus schmitti* BURKENROAD 1936

por

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Extracto

La pesca del camarón blanco (*Penaeus schmitti* Burkenroad) constituye una actividad de considerable importancia.

Con el fin de obtener mejores conocimientos sobre este recurso, se realizaron investigaciones de las cuales algunos resultados aparecen en el presente trabajo.

Se presentan algunos datos sobre la distribución geográfica de la especie y las relaciones ecológicas. Además están incluidos los resultados sobre: capturas, esfuerzo pesquero, distribución por tamaños, relación numérica y por sexos y hábitos alimenticios del camarón blanco.

E/66

NOTES ON FISHERIES BIOLOGY ON THE WHITE SHRIMP, Penaeus schmitti BURKENROAD 1936

Abstract

The white shrimp (Penaeus schmitti Burkenroad) supports a major fishing industry.

With a view to obtaining fuller information on this resource, research has been conducted and some of the findings so far obtained are given in this paper.

Findings are reported with respect to geographical distribution and ecological relations. In addition, the authors report results on catches, fishing effort, size distribution, sex ratio, and feeding habits of the white shrimp.

NOTES BIOLOGICO-HALIEUTIQUES SUR LA CREVETTE Penaeus schmitti BURKENROAD 1936

Résumé

La pêche de la crevette Penaeus schmitti Burkenroad constitue une activité d'importance considérable.

Afin d'approfondir les connaissances sur cette ressource, on a organisé des enquêtes dont le présent document expose les résultats.

On y trouve des données sur la répartition géographique de cette espêce et sur ses rapports écologiques. Le document donne en outre les résultats des études concernant les prises, l'effort de pêche, la répartition par dimensions, par effectifs et selon le sexe, et les habitudes alimentaires de la crevette Penaeus schmitti Burkenroad.

1 INTRODUCCION

Según los datos bibliográficos (Burkenroad, 1936; Anderson y Lindner 1943; Pérez-Farfante, 1953 y 1954; Voss, 1955; Lidner, 1957; Holthuis, 1959; Sadowski y Radasewski, 1960; Eldred y Hutton, 1960 y Boschi, 1963) el camarón blanco está distribuido en las áreas costeras del Atlántico y del Mar Caribe entre 28° latitud N (Cabo Cañaveral, Florida, E.U.A.), y 28° latitud S (Laguna, Brasil).

En Cuba las mayores concentraciones se hallan en la plataforma sudoriental. Las menores capturas se dan en algunas bahías de la costa norte. Hasta el presente no se conoce esta especie en las aguas de la costa sudoccidental (Fig. 1).

Debido a que las capturas de camarón blanco contribuyen con un 34 porciento aproximadamente a las totales anuales de los camarones, se ha llevado a cabo este estudio con el fin de poder realizar la pesca racional de dicho recurso.

2 MATERIALES Y METODOS DE TRABAJO

Se estudiaron aproximadamente 15.300 camarones de los cuales 5.700 (37 porciento) eran blancos (P. schmitti) provenientes de las principales áreas pesqueras. Se tomaron dos medidas de longitud: el largo total (Lt_2) que se midió desde la escotadura postorbital hasta el borde posterior del último segmento abdominal en su punto medio y el largo de cefalotórax (Lc_2) desde la escotadura postorbital hasta el punto medio dorsal del borde posterior del cefalotórax. Se agruparon las medidas tomadas en milímetros con intervalos de 5 mm utilizando el punto medio como representante de cada clase (p.e. 71-75 mm = clase 73).

Para establecer el peso se juntaron los individuos medidos por clases establecidas, utilizando para ello una caja con divisiones y anotando el peso correspondiente en gramos.

La temperatura se determinó utilizando termómetro con medio grado de exactitud. La salinidad se determinó en el laboratorio según el método Mohr-Knudsen. El contenido de oxígeno se obtuvo en el laboratorio según el procedimiento de Winkler.

La concentración del ión-hidrógeno (pH) se determinó con el colorímetro visual utilizando metacresol y bromotimol como indicadores, en algunas muestras se utilizaron papeles pH con valores entre 6,8 y 8,4.

Para determinar la penetrabilidad en los sedimentos de los fondos camaroneros se utilizó un penetrómetro japonés y a veces una vara metálica con 1 cm de espesor aproximadamente. Para determinar el esfuerzo pesquero con attaraya se tomaron 45 casos al azar y al mes en cada subarea de Manzanillo.

3 CARACTERISTICA DE LAS AREAS PESQUERAS Y RELACIONES ECOLOGICAS

A lo largo de nuestras costas desembocan más de 200 ríos (Furrazola et al., 1964) entre ellos: el Sevilla, Najasa, Jobabo, Zaza y Cauto los cuales resultan ser sumamente importantes para la pesca de camarones. Existen también numerosas ensenadas, esteros, lagunas y áreas pantanosas que son verdaderos "criaderos naturales" para los estadios juveniles.

Los camarones blancos habitan preferentemente en fondos compuestos de arena, arcilla, caliza y grava, que en diversas proporciones, junto a residuos orgánicos (detritos) forman sedimentos fangosos que van desde el gris claro hasta el oscuro, siendo muy variables la profundidad y la penetrabilidad.

La influencia de las lluvias es muy notable en la vida del camarón y sus capturas (Hildebrand y Günther, 1953, 1954). La salinidad de las aguas varía considerablemente (de 12,76 a 49,25°/oo) debido a las lluvias, pero también a la poca profundidad y evaporación durante las sequías. Sin embargo las salinidades más frecuentes oscilaron entre 30

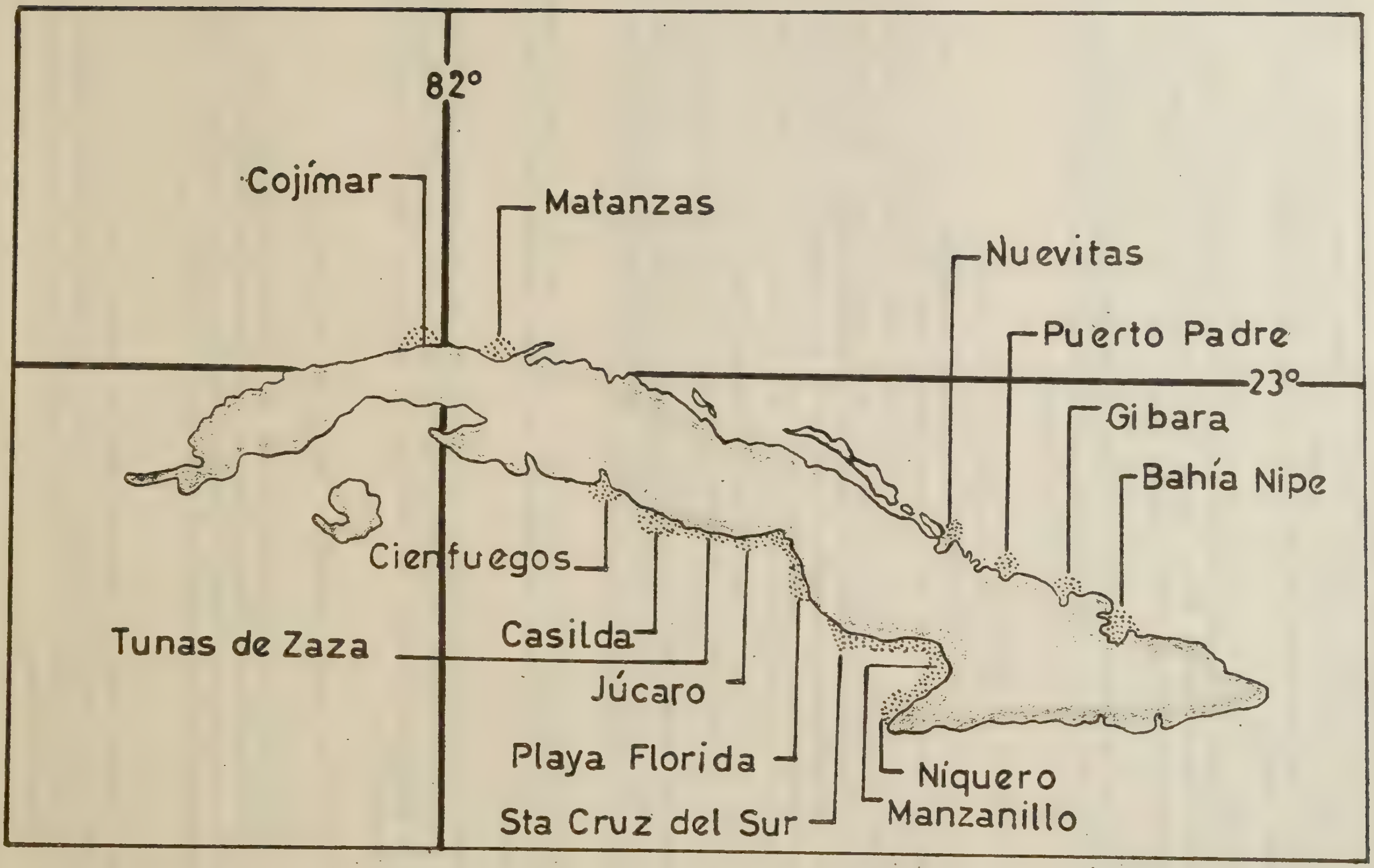
82°
23°
Cojímar
Matanzas
Nuevitas
Puerto Padre
Gibara
Bahía Nipe
Cienfuegos
Tunas de Zaza
Casilda
Júcaro
Playa Florida
Sta Cruz del Sur
Niquero
Manzanillo

Fig. 1 Distribución geográfica de Penaeus schmitti por áreas pesqueras cubanas.

y 35°/oo y el contenido de oxígeno entre 1,94 ml/l (Laguna de Hoyos, Tunas de Zaza, en septiembre de 1965) y 5,92 ml/l (Punta Gándula, Laguna de Guanaroca, Cienfuegos, en mayo del mismo año). La concentración del ión-hidrógeno (pH) varió entre 7,7 y 8,2, resultando más estables estos fenómenos en aguas adyacentes. La temperatura del agua también varió registrándose en los meses de enero y febrero hasta 17°C y en los de verano como junio y julio hasta 34°C, oscilando las más frecuentes entre 26° y 30°C.

4 ARTES Y METODOS DE PESCA

Se usan diversos medios para la captura de camarón como: atarraya de brioles, con o sin "engodo" (cebo colocado sobre el fondo), prefiriendo para ello aguas menos profundas, aproximadamente hasta 6 m; red de sitio (biturón) en los esteros, lagunas, zanjas, etc., donde la profundidad oscila entre 1 y 3 m y red de arrastre con puertas (portalones) de tipo balón, semi-balón y planas (mexicana, americana y japonesa) en las aguas adyacentes de mayores profundidades (10 a 20 m).

5 NOTAS BIOLOGICO-PESQUERAS

5.1 Las capturas

Los datos estadísticos sobre las capturas en la plataforma cubana, señalan que los mariscos (langosta, camarón y ostión) aportan aproximadamente el 30 porciento al volumen total. Los camarones contribuyen a las capturas de dichos mariscos con un 20 porciento y a las capturas totales nacionales durante los últimos 10 años entre 3 y 6 porciento. Estas capturas constituyen dos especies que son: camarón acaramelado (*Penaeus duorarum*) y camarón blanco (*Penaeus schmitti*).

Las áreas de mayores capturas son: Manzanillo, Sta. Cruz del Sur (con sus áreas pesqueras de Cayo Granada, Río Sevilla, Banco del Chinchorro) y Tunas de Zaza. Los promedios de las capturas anuales en los últimos 5 años de las tres áreas mencionadas son de 1.571 t y los de las otras, donde se captura unicamente camarón acaramelado de 704 t.

Se observó (Fig. 2) que en todos los años estudiados las capturas de camarón blanco aumentan considerablement después de las abundantes lluvias y de fuertes tormentas tropicales. Ejemplo de esto es que al paso del ciclón "Flora" (octubre 1963) en noviembre aumentaron en un 150 porciento, en diciembre en un 300 porciento y en un 100 porciento durante todo el año de 1964, con respecto al promedio mensual de los primeros 10 meses de 1963. Aún en los meses de menores capturas (julio y agosto) éstas aumentaron cuando ocurrieron estos fenómenos.

5.2 Esfuerzo pesquero

Puesto que majoria de las capturas se realizan con attaraya y en el area de Manzanillo se efectuaron estudios de esfuerzo pesquero y obtuvieron los siguentes promedios para los años 1965-1966: se emplearon 6,4 dias por cada viaje, en las faenas participaron 2 pescadores, la captura total de camarones por viaje fue de 126,3 kg y la de pescador por dia 8,8 kg.

5.3 Relación numérica entre ambas especies, distribución por tamaños y sexos en distintas áreas y temporadas

Según el arte de pesca, el área, parte del día y temporada, las relaciones numéricas entre ambas especies commerciales presentes en las faenas, varía considerablement. Puede resultar que una de las dos especies esté completamente ausente en las capturas de un área determinada, sin embargo, en otra area en el mismo tiempo, o en la misma, durante otra parte del día, constituye más del 50 porciento de la faena.

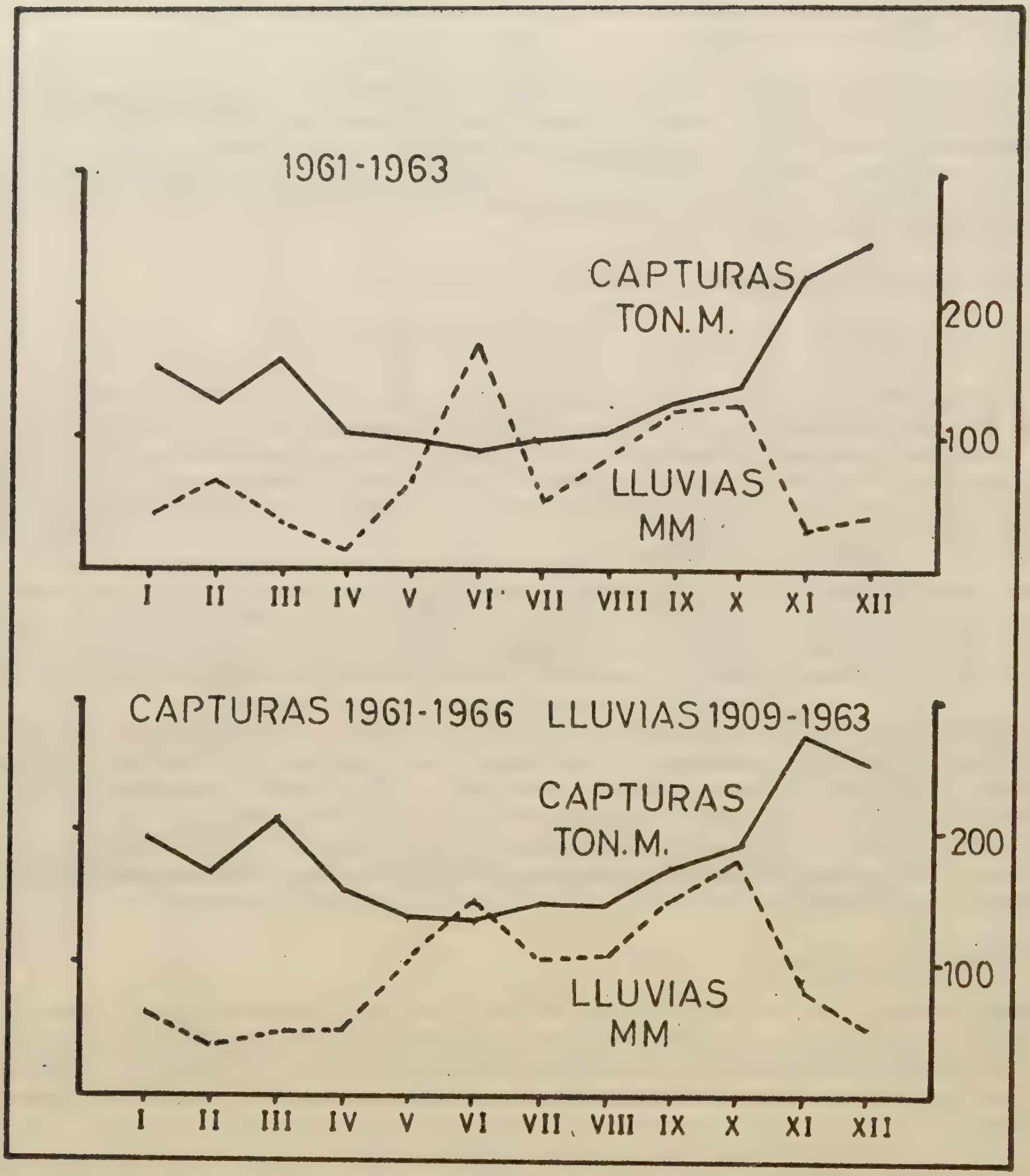

Fig. 2 Promedios de las capturas y las lluvias por meses.

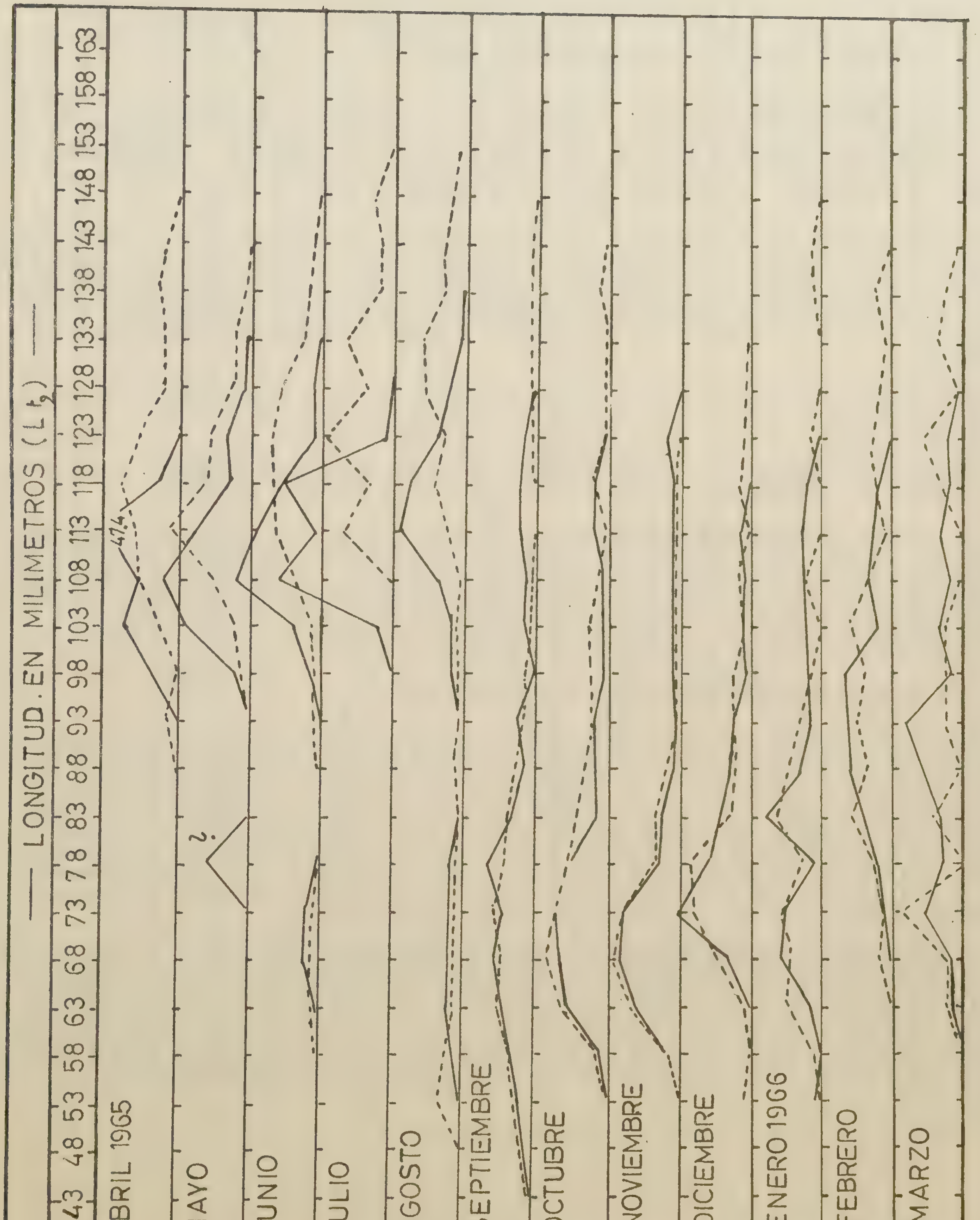

Fig. 3 Distribucion por tamaños y sexos de *Penaeus schmitti* capturados con attaraya en Manzanillo, 1965-1966. ——— = ♂ - - - - - = ♀

Los individuos de tamaño comercial se capturan desde las aguas interiores con poca profundidad (30 cm) hasta 9 millas náuticas lejos de la costa y en profundidades hasta 20 m. En las aguas menos profundas la distribución por tamaños fue entre 43 y 153 mm y en mayores profundidades entre 53 y 138 mm de largo total.

El porcentaje de los individuos menores de tamaño comercial de P. schmitti es menor en las áreas alejadas de la costa (0 a 9.8 porciento) y mayor en las áreas cercanas a ésta (21.1 a 55,6 porciento). Basándose en los datos obtenidos en Manzanillo 1965-1966 (Fig. 3) los individuos de mayores tamaños se capturan entre abril y agosto y los de menor tamano a partir de septiembre; esto último se comprobó también en Tunas de Zaza.

Hay diferencias en la amplitud de las clases entre ambas especies y entre sexos. Estas dependen del área (en las aguas interiores es menor) y de la temporada (la menor amplitud entre marzo y mayo y la mayor en verano en las aguas adyacentes a Manzanillo). Las clases modales son de menor longitud para camarón acaramelado; los machos de ambas especies tienen clases modales de menor longitud que las hembras, las cuales siempre alcanzan los mayores tamaños.

Los camarones blancos son omnívoros con hábitos alimentarios canibalescos y se alimentan principalmente en el fondo pero también en las aguas próximas a éste.

En muy raras ocasiones se encontraron individuos con musculatura abdominal blanda y de color lechoso que corresponde a la enfermedad descrita por Hutton et al. (1959).

La captura adicional está constituida por especies muy variadas, aunque en su mayoría son peces. Una gran parte de estos son de menor valor comercial; en ciertas temporadas y áreas se capturan ejemplares subadultos de algunas especies que se explotan comercialm nte y raramente hay en las redes un número elevado de otros organismos con alto valor comercial. Las considerables cantidades de "captura adicional" en la pesca con redes de arrastre con puertas se podrían utilizar en la obtención de harina de pescado.

5.4 Algunas consideraciones acerca del ciclo vital

Los lugares de desove se encuentran presumiblemente en la plataforma debido a que los ejemplares de camarón blanco nunca se capturan ni lejos de la costa ni fuera de la plataforma. Todo indica que el desove ocurre entre marzo y septiembre en aguas algo profundas (más de 5 m) de la plataforma con salinidades y temperaturas más estables que en las aguas interiores y adyacentes a la costa. Los estadios larvales se encontraron en el plancton obtenido en varias áreas de la plataforma durante 1965 y 1966, probablemente traidos por la corriente favorable inmigrando hacia las costas y aguas interiores. Los estadios postlarvales y juveniles residen en las aguas interiores llamadas también "criaderos naturales" (ejemplo: Palmares, Laguna, Guanaroca, Cienfuegos, octubre 1965).

Durante los meses de febrero, marzo y abril los adultos abandonan las aguas interiores. Por ejemplo, en las aguas interiores de Tunas de Zaza, las capturas disminuyeron considerablemente en estos meses (1965, 1966). Los pescadores manifiestan que el camarón "dicta la veda por si mismo". En un área pesquera, como por ejemplo, Manzanillo, se capturaron durante el recorrido de doce meses camarones con amplitud de las clases muy grande y con dos clases modales, lo que hace pensar que hacia esta área migran anualmente dos generaciones (Fig. 4 y 5).

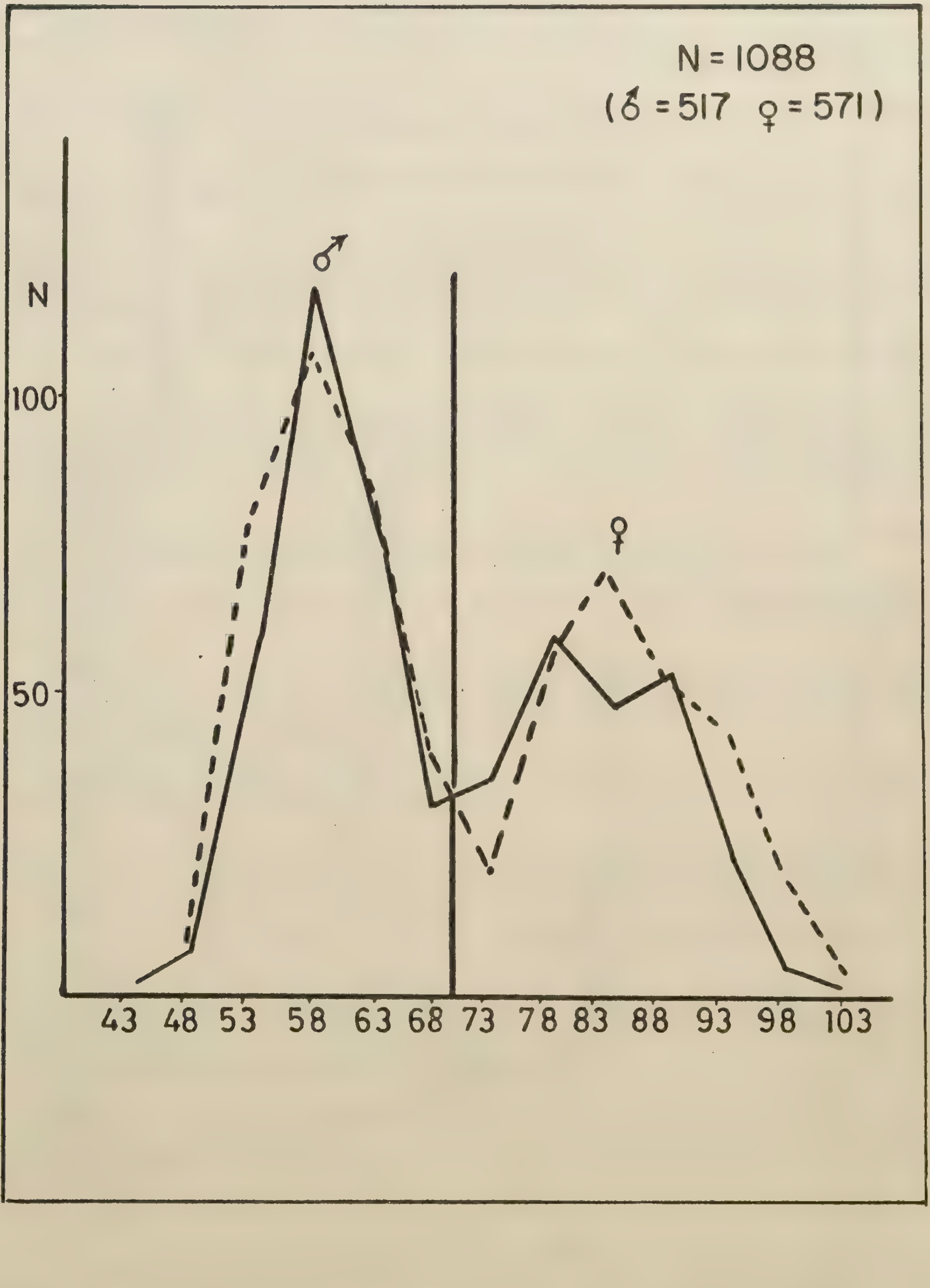

Fig. 4 Composición por tamaños y sexos de Penaeus schmitti capturados con atarraya en Tunas de Zaza (1965).

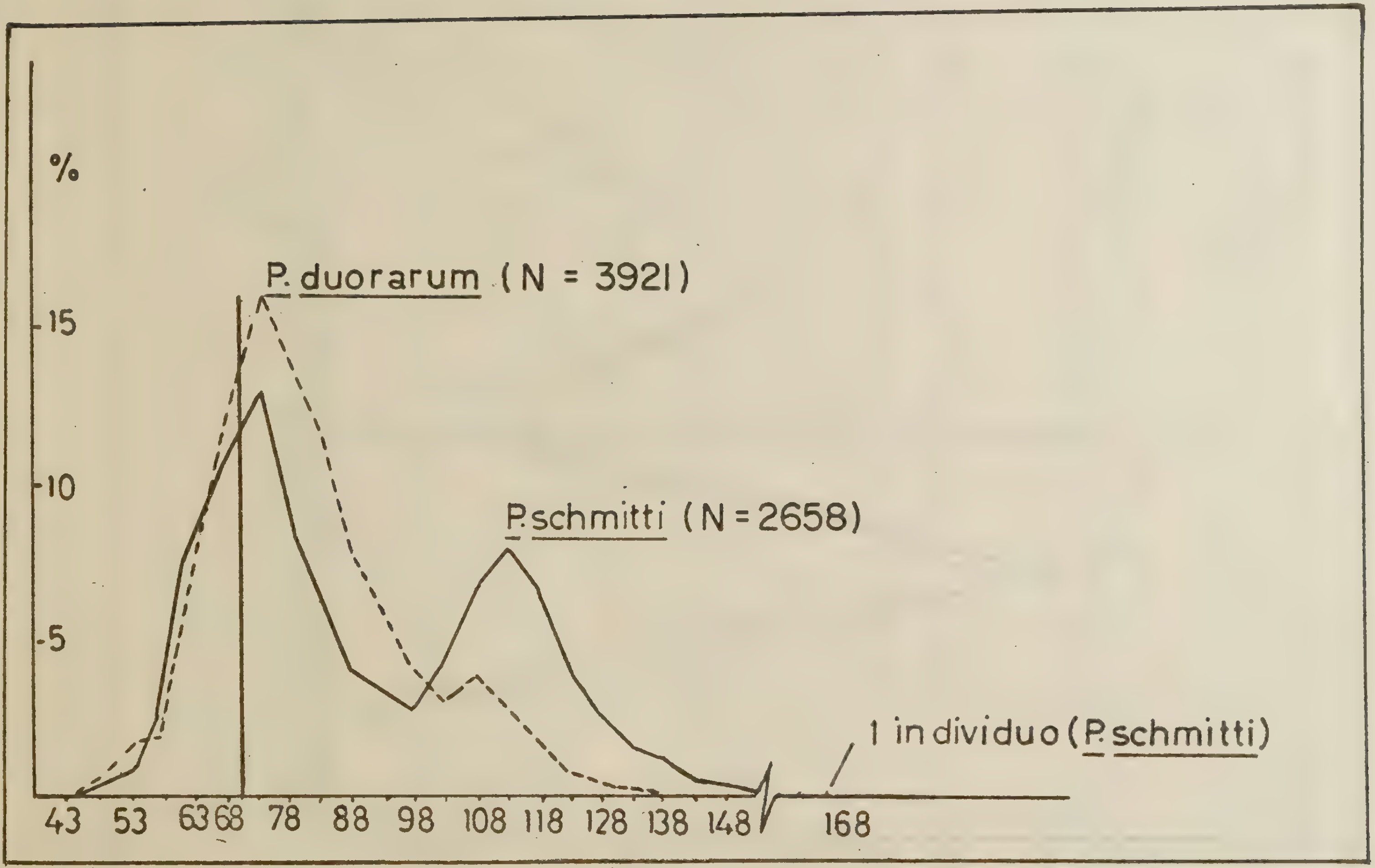

Fig. 5 Composicion por especies, sexos y tamaños de camarones comerciales (*P. duorarum* y *P. schmitti*) capturados con atarraya en Manzanillo 1965-1966.

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A BRIEF HISTORY OF FLORIDA'S LIVE BAIT SHRIMP FISHERY WITH DESCRIPTION OF FISHING GEAR AND METHODS

by

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Abstract

A brief history of the live bait shrimp fishery of Florida is given as well as descriptions of the methods of capture of the three major bait species.

The present fishery is growing in direct proportion to the growth of tourism and recreational fishing in Florida and it is expected that the bait shrimp fishery will capture more and more of the same shrimp that traditionally have been taken on the offshore grounds.

The major portion of the shrimp catch from Florida estuarine areas is now being caught by roller-frame trawls. The roller-frame trawl evolution is described and construction features of the most advanced design given.

The roller-frame trawls are probably not destructive to the estuarine habitat. Methods of fishing, handling the catch, and kinds of organisms caught are described.

The roller-frame trawls of modern design are relatively inexpensive and easy to construct. They should be adaptable to a wide variety of uses in estuarine areas of the world where shrimp stocks are not now being exploited.

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E/67

BREF HISTORIQUE DES PECHERIES DE CREVETTES UTILISEES COMME APPAT VIVANT EN VIVANT EN FLORIDE ET DESCRIPTION DES ENGINS ET DES METHODES DE PECHE

Résumé

Les auteurs retracent succinctement l'historie des pêches à la crevette utiliseé comme appât vivant en Floride, et décrivent les méthodes de capture des trois principales espèces employées à cette fin.

A l'heure actuelle, cette activité se développe de manière directement proportionnelle à l'expansion du tourisme et de la pêche recréative en Floride, et l'on pense qu'elle aura à son actif une part croissante des crevettes capturées jusqu'ici sur les hauts fonds.

La majeure partie des crevettes capturées dans les estuaries de Floride sont maintenant prises par des chaluts avec des cadres à rouleaux (roller-frame trawls). L'évolution de cette technique est décrite et le document reproduit les plans de construction les plus modernes.

Le chalut avec cadre à rouleaux n'abime sans doute pas l'habitat des estuaires. Les méthodes de pêche, la manutention de la prise et le type d'organisme capturé sont décrits.

Le chalut moderne avec cadre à rouleaux est relativement peu côuteux et facile à construire. Il doit être possible de l'adapter à des usages multiples dans les estuaires où les stocks de crevettes ne sont pas exploités à l'heure actuelle.

BREVE HISTORIA DE LA PESCA DE CAMARON PARA USARLO COMO CEBO VIVO EN FLORIDA, Y DESCRIPCION DE METODOS Y ARTES DE PESCA

Extracto

Se da una breve historia de la pesca del camarón para usarlo como cebo vivo en Florida, así como descripciones de los métodos de captura de las tres principales especies de cebo.

Actualmente la pesca aumenta en relación directa con el crecimiento del turismo y de la pesca recreativa en Florida, esperándose que con la oferta de camarón vivo para cebo, se aumentará la captura de los que tradicionalmente se han pescado en los bancos de alta mar.

La mayor parte de las capturas de camarones en los estuarios de Florida se obtiene con redes de arrastre de marco con rodillos. Se describe la evolución de éstas y se indican las características de la construcción de las más avanzadas.

Las redes mencionadas probablemente no destruyen al habitat del estuario. Se describen los métodos de pesca, la manipulación de la captura, y las clases de organismos capturados.

Las redes de arrastre de marco con rodillos modernas son relativamente baratas y fáciles de construir. Deberían adaptarse a una extensa variedad de usos en las zonas de todos los estuarios del mundo en los que se explotan actualmente poblaciones de camarones.

1 INTRODUCTION

The valuable offshore fisheries for shrimp, Penaeus setiferus (Linnaeus), P. aztecus Ives, and P. duorarum Burkenroad, of Florida have been studied for about 20 yr (Idyll, 1957; Joyce and Eldred, 1966) but less investigation has been made of the bait fishery conducted in coastal bays, lagoons and estuaries for juveniles of the same species. The bait shrimp fishery has grown rapidly in importance and has reached an efficient stage of development. There is a heavy demand for live bait shrimp by the recreational fishery of Florida, and considerable quantities of dead bait shrimp are also marketed.

Study of the bait shrimp fishery is important for several reasons. It is exploiting the same shrimp as the offshore fleet, and there may be conflict over future division of the catch. Then, anglers are sometimes concerned that damage may be done to the bay habitat and to young sport fish by the bait shrimpers. In addition, the roller-frame trawl now being used by a majority of the bait shrimpers in Florida is an efficient gear which should prove adaptable in tropical estuaries around the world.

Statistics of this fishery are collected by the Florida State Board of Conservation (Welch, 1965; Jones and Smith, 1966). In 1965, bait shrimp were caught and landed in 25 coastal counties of Florida. During that year 94,698,386 live shrimp and 218,000 kg of dead bait shrimp worth near $1,460,000 at the wholesale level were reported. Retail values may be as much as three times that at the wholesale level.

Year-to-year fluctuations in landings from Nassau, Monroe and Santa Rosa counties suggest that annual abundance changes markedly in some areas (Table I). Counties having the largest estuarine areas generally produce the highest catches of bait shrimp. If man alters these estuarine "nursery grounds" by pollution and other adverse activities, both the bait and the offshore fisheries will suffer decreases in catch.

2 HISTORY OF THE FISHERY

The bait shrimp industry in Florida probably originated from a need by commercial hook and line fishermen for live bait for spotted seatrout, Cynoscion nebulosus (Cuvier), (Tabb, 1960; de Sylva, 1954). Tourists quickly learned of the value of live shrimp for sport angling, and the bait shrimp industry has risen in direct proportion to the increase in tourism in Florida. Until 1954, the bait shrimp fishery was centered in northeastern Florida between Cape Kennedy and Jacksonville. The white shrimp, P. setiferus, was caught most abundantly in the northern part of that sector while brown, P. aztecus, and pink shrimp, P. duorarum, were most important in the southern part. The fishery in northeast Florida operated originally on diurnal white shrimp which were caught by beach seine, cast net and otter trawls. The nocturnal brown and pink shrimp were fished later, using dipnets or channel nets. The latter are conical bags of 3/4- to 1-in stretched mesh netting attached to an iron pipe or reinforcing rod frame and suspended in the upper part of the water column from a bridge or from an anchored boat. This type of fishing is most successful during the monthly new and full moon ebb tides. Channel nets (Fig. 1) are still used in various parts of the state.

Dipnets were first used in conjunction with kerosene lanterns but the gear was probably not effective until the development of the "Coleman" gasoline lantern. Thousands of dipnet-Coleman lantern combinations are now in use in the bait shrimp fishery as well as in a rapidly growing recreational shrimp fishery. Although the dipnet fisherman sometimes catches large numbers of shrimp, his catch depends on surface runs of shrimp which are unpredictable; hence this gear cannot supply the present heavy demands of the bait industry.

The pushnet gear was apparently developed in northeast Florida near New Smyrna Beach about 1950 (de Sylva, 1954; Allen and Inglis, 1958). With this gear, one man can capture shrimp day or night, with 8-h catches ranging from 200 to 5,000 shrimp. Catches with the pushnet vary from 6 to as high as 400 shrimp per "push", depending on season and fishing area. In 1954 an estimated 1,300 people made their living exclusively from

TABLE I

Landings of live bait shrimp by counties, in Florida, during the years 1963, 1964 and 1965 (after Joyce and Eldred, 1966)

County	Numbers of live shrimp 1963	1964	1965
Bay	439,453	356,999	169,372
Charlotte	23,000	-	-
Citrus	3,113,030	3,826,615	944,[illegible]47
Collier	16,500	-	-
Dade	20,812,557	24,629,847	26,677,448
Dixie	1,672,150	795,300	1,435,000
Duval	211,000	276	8,312
Escambia	110,474	171,059	232,133
Gulf	106,700	197,553	254,772
Hernando	40,100	65,000	-
Hillwborough	7,500	-	70,000
Lee	3,852,595	2,411,070	3,068,277
Levy	6,497,917	1,938,367	94,950
Manatee	3,227,780	2,419,582	2,262,370
Martin	369,450	411,410	387,000
Monroe	735,207	272,700	347,250
Nassau	285,256	585,400	128,700
Okaloosa	33,300	22,400	3,000
Pasco	15,612,364	14,912,788	28,370,133
Pinellas	25,620,897	26,274,528	26,680,667
Santa Rosa	327,231	159,307	82,588
St. Johns	19,500	6,000	12,000
St. Lucie	234,135	1,178,667	209,500
Sarasota	614,000	234,250	90,300
Volusia	5,981,325	3,969,905	3,170,167
Totals	89,963,421	84,839,523	94,698,386

bait shrimp in the area between Jupiter and Jacksonville on the Florida east coast; pushnets supplied most of the shrimp taken by these people. The present industry, with its efficient facilities for holding large numbers of shrimp and transporting them elsewhere in the state, began with the pushnet fishery. Many of the present bait shrimp wholesalers started their businesses in the fishing area near New Smyrna Beach and Jacksonville.

Since 1954, when the pushnet fishery was at its peak in northeast Florida, the industry has expanded rapidly. Its present important economic status is an outgrowth

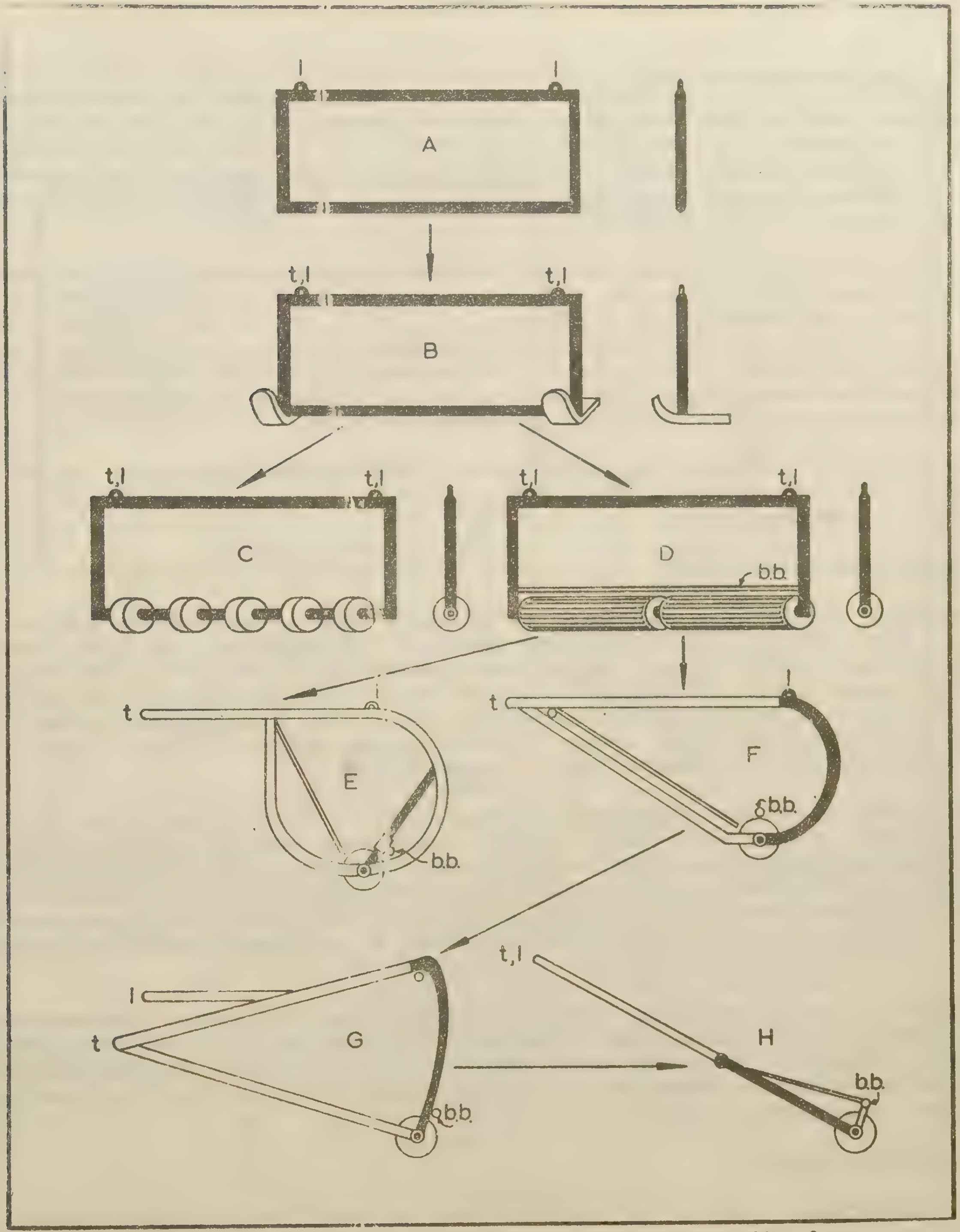

Fig. 1 Diagramatic presentation of the evolution of the roller-frame trawl from the channel net through the "long yoke" and "short yoke" designs and culminating in the Still trawl (H).

A = the channel net, equipped for lifting only
B = the skid-equipped channel net frame (Higman, 1952)
C = the wheel-equipped channel net frame (Higman, 1952)
D = the roller-frame trawl of earliest known design
E = west Florida "long yoke" frame (Woodburn, *et al.*, 1957)
F = Biscayne Bay "long-yoke" frame (Tabb, 1958)
G = Still "short-yoke" trawl frame (Tabb, 1958)
H = Still trawl of 1967 illustrating return to basic
 simplicity of D but with important modifications

The basic features of the channel net frame have been retained by all these designs and are indicated in black. Design C was a dead end, the wheels apparently failing to provide sufficient bearing surface.

of the increase in tourism in Florida which began shortly after the second world war. Many tourists come to fish, and spotted seatrout, caught with live shrimp, is a favored species. At present the pink shrimp is believed to be the most heavily exploited bait species, with brown shrimp second. In Dade Country, southeastern Florida, another species of shrimp, Penaeus brasiliensis Latreille, is also important, and is caught with pink shrimp (Saloman, Allen and Costello, 1968).

Anglers often complain that the bait shrimpers cause destruction of the bay bottom and of small sport fish. This has stimulated several studies. The bait shrimp fishery of west Florida was described by Woodburn et al.(1957), and by Futch and Beaumariage (1965). Tabb (1958) and Siebenaler (1953) described the Biscayne Bay fishery of southeast Florida, and Higman (1952) reported on shrimping in Florida Bay and the Florida Keys. These studies have concluded that the roller trawls, also called "side-frame" or "roller-frame" trawls, do not harm the estuarine biota.

The fishery of Biscayne Bay, Dade County, Florida, now produces the second largest landings of live bait shrimp in the state, and because it is typical of such fisheries elsewhere, is described below.

3 THE BISCAYNE BAY FISHERY

Siebenaler (1953) reported 3 bait shrimp boats working in Biscayne Bay during 1952 and 1953. These boats fished mainly from December through March. By 1958, there were 12 boats fishing in the bay, and fishing was year-around (Tabb, 1958). By 1966, bait shrimp boats were placed under a permit system and 46 vessels were fishing in Biscayne Bay. A few of these boats came from as far as Tampa Bay, Charlotte Harbor and Fort Myers on the Florida west coast during times of shrimp scarcity there. These return to their home waters when catches decline in Biscayne Bay.

Until 1958, there were three main fishing areas in Biscayne Bay (Fig. 2). Area A has muddy sand bottom; area B has sparse to heavy seagrass, Thalassia testudinum and Cymodocea manatorum; area C has muddy sand bottom with higher organic content than either A or B, and brown alga is dominant. Bait shrimping has been restricted to the bay south of Rickenbacker Causeway since 1953. There are also prohibitions against fishing too near the mainland shore in areas known to be spotted seatrout fishing grounds.

At present, only areas B and C are being fished heavily; area C now receives the greatest fishing effort because the shrimp are often too small for market in the shallower parts of area B. The otter trawl, once used mainly in area A during winter runs of large shrimp, has almost disappeared from the fishery and has been replaced by the roller-frame trawl described below.

4 ROLLER-FRAME TRAWLS

The roller-frame trawl in its earliest form was described by Higman (1952). Since then this type of gear has been constantly modified and improved (Fig. 1). In 1958, Tabb described two types of roller-frame trawls, the "long-yoke" and "short-yoke" roller-frame trawls, that were in common use in Biscayne Bay. These names referred to the configuration of the trawl frames when viewed from the side (Fig. 1, E and F). The long-yoke trawl frames tended to fall forward when used over rough and uneven bottom and when lift was applied at the termination of each drag, causing the towing point to plow the bottom. This increased the amount of debris collected. Because short-yoke trawls of a design invented by Robert Still of Miami (Fig. 1, G) plow less without materially reducing the shrimp catch, fishermen have been required, by State regulation, to use the short-yoke design. The short-yoke trawl did not over-balance the frame because of better weight distribution, and because the towing and lifting points were so close together. Mr. Still subsequently refined his short-yoke design to the most recent configuration (Fig. 1, H).

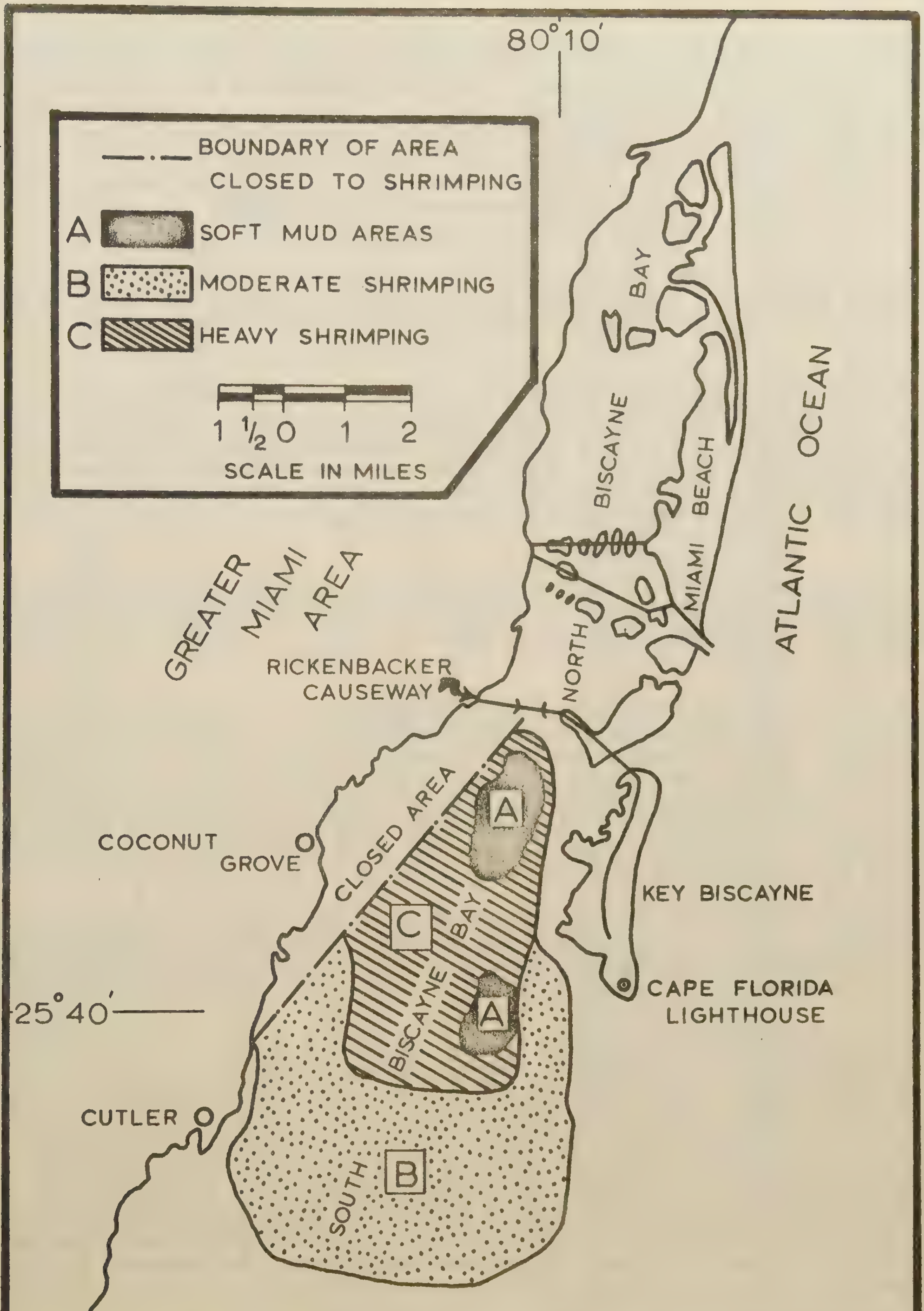
80°10'
BOUNDARY OF AREA CLOSED TO SHRIMPING
A SOFT MUD AREAS
B MODERATE SHRIMPING
C HEAVY SHRIMPING
1 ½ 0 1 2
SCALE IN MILES
BISCAYNE BAY
MIAMI BEACH
ATLANTIC OCEAN
GREATER MIAMI AREA
RICKENBACKER CAUSEWAY
NORTH
CLOSED AREA
COCONUT GROVE
KEY BISCAYNE
CAPE FLORIDA LIGHTHOUSE
25°40'
BISCAYNE BAY
CUTLER
SOUTH
A
C
B

Fig. 2 The location of bait shrimp fishing grounds of Biscayne Bay, Dade Country, Florida (after Tabb, 1958).

Rollers on the trawls used in the Biscayne Bay fishery prior to 1958 ranged between 4 and 7 in* in diameter, averaging 5 in. Some opposition was expressed against the use of these trawls, observers contending that the slats on the rollers (which were 3/8-in pipe or 1/2-in solid rods) should be eliminated in favor of smooth rollers, because the slats were thought to damage bay bottom life. But observations have indicated that rollers should be slatted in order that they grip the bottom and turn freely; otherwise they bind and act as scrapers. Rollers of not less than 5 in in diameter are required to prevent bogging and scraping in soft bottom.

The roller-frame trawls now in use in the Florida bait shrimp fishery are efficient, and they catch shrimp with little trash at low operating costs. The trawl is probably the most advanced in the industry, and most fishermen in Biscayne Bay have converted to this gear.

The design of the Still trawl is shown in Figs. 3 and 4. The essential features of roller, strainer bars and "breaker bar" of the older designs (Fig. 1) have been retained. All other framing features have been eliminated with a corresponding saving in weight and construction costs. The Still trawl has also eliminated the need for separate lifting and towing points required on the long-yoke trawls, and the construction assures that the net frame will not fall forward during towing or lifting, even over rough bottom.

The net position in relation to the frame has been simplified by the use of a fixed breaker bar as opposed to the adjustable bar of earlier models. In the design illustrated, this bar is set at the point most efficient for fishing in the vegetated areas of Biscayne Bay.

The weight of the net frames has been reduced from about 400 lb to about 250 lb (181 to 113 kg). The simplicity of the new frames makes it possible to assemble them, using flat jigs. The new frames cost $60.00 each, of which $40.00 is for material and $20.00 for labor, chiefly welding at $3.00 per h. Although the design presented here is for a 12 ft (3.6 m) frame, smaller frames can be made by reduction of the horizontal scale and by using two rather than three rollers. Frames of the 12 ft width as illustrated are fished from vessels of 42 to 50 ft (13 to 15 m) length; 20 to 24 ft (6 to 7 m) vessels would fish frames of 6 to 8 ft (1.8 to 2.4 m).

These trawls are fished normally in the 10-to 16-ft (3 to 5 m) depths of Biscayne Bay but they are efficient at greater depths. The nets should be set while the vessel is under way since tension on the warp is required to prevent turning of the frame on the way to the bottom in deep water.

Vessels using the new roller-frame trawls are rigged like Gulf of Mexico shrimp trawlers fishing two 40-ft otter trawls (Robas, 1959). This is desirable, especially for fishing deeper water, but in shallow water a double davit arrangement can be employed (Woodburn, et al., 1957, p. 16-17). Pulleys are attached at the outboard ends through which the lifting line can be fed out and recovered from a deck-mounted winch. In such vessels, the towing lines are the same as the lifting lines. In older net frame designs, the lifting lines from the winch are attached to a point on the top of the frame near the center of gravity, while the towing lines are attached to the towing yoke (Fig. 1); the towing lines are set for the depth to be fished and attached to the bow of the vessel. The Still trawl has eliminated the need for separate lifting and towing lines.

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* 1 in = 1 inch = 2.54 cm: Other metric equivalents are given in Figs. 3 and 4. Ed.

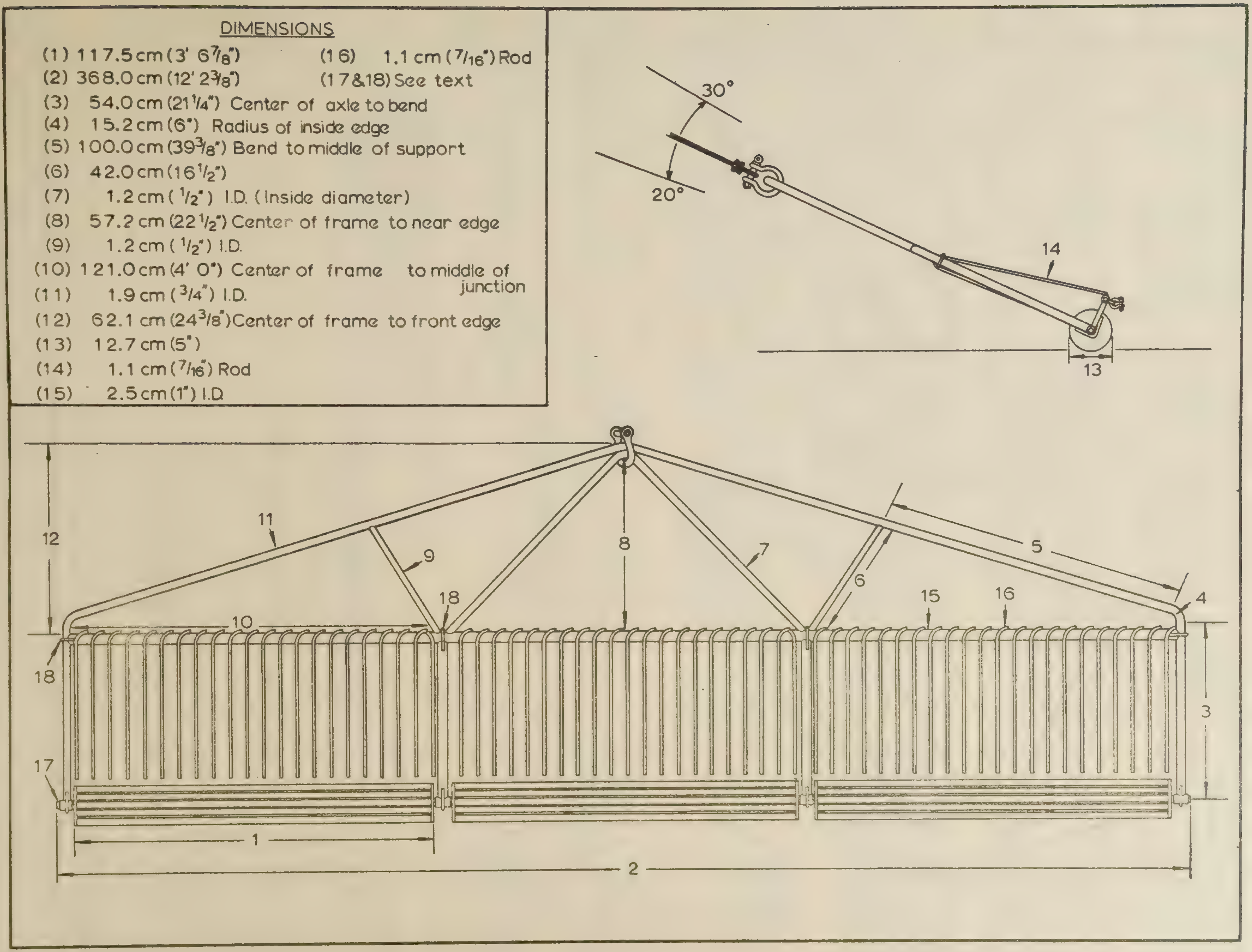
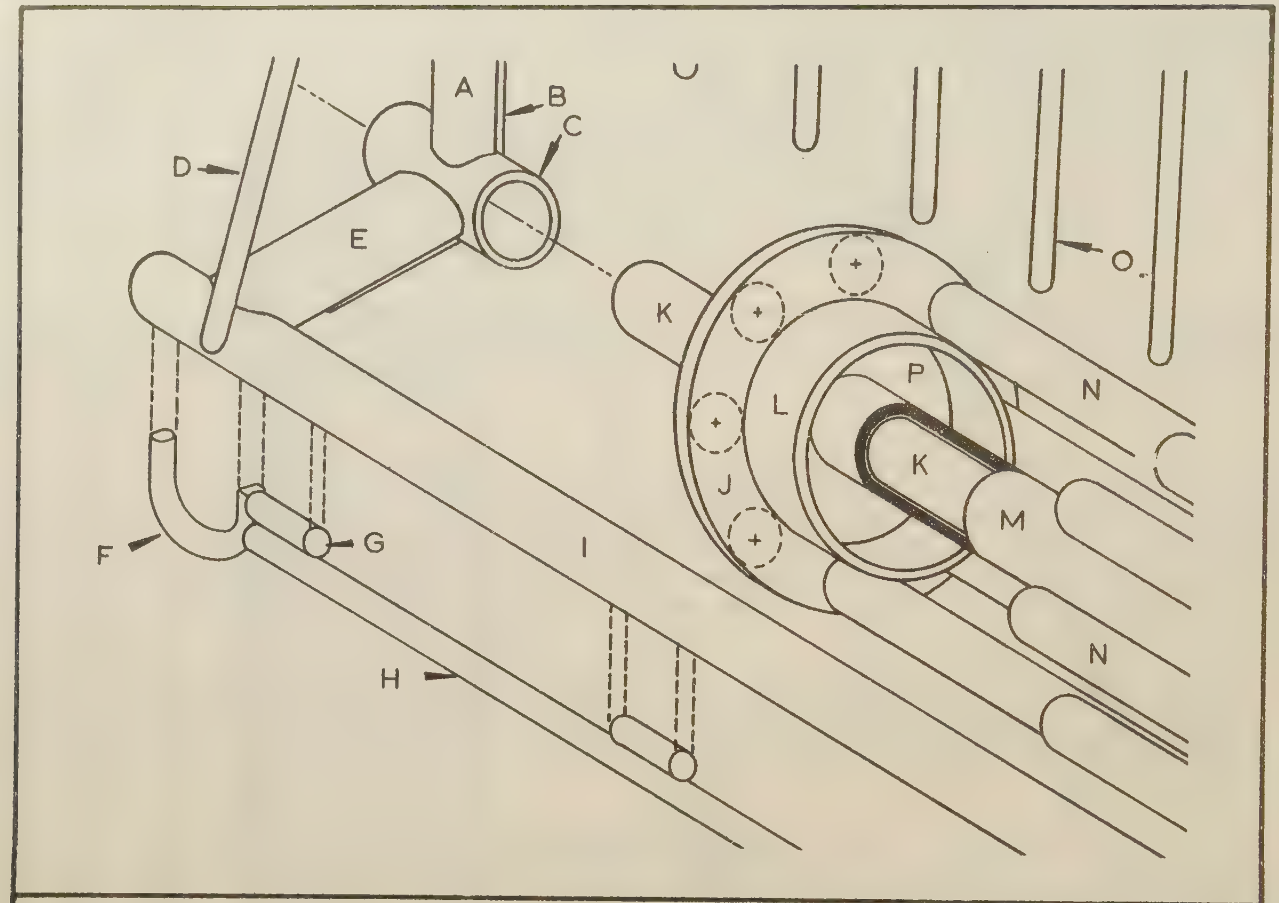

DIMENSIONS
(1) 117.5 cm (3' 6⅞")
(2) 368.0 cm (12' 2⅜")
(3) 54.0 cm (21¼") Center of axle to bend
(4) 15.2 cm (6") Radius of inside edge
(5) 100.0 cm (39⅜") Bend to middle of support
(6) 42.0 cm (16½")
(7) 1.2 cm (½") I.D. (Inside diameter)
(8) 57.2 cm (22½") Center of frame to near edge
(9) 1.2 cm (½") I.D.
(10) 121.0 cm (4' 0") Center of frame to middle of junction
(11) 1.9 cm (¾") I.D.
(12) 62.1 cm (24⅜") Center of frame to front edge
(13) 12.7 cm (5")
(14) 1.1 cm (7/16") Rod
(15) 2.5 cm (1") I.D
(16) 1.1 cm (7/16") Rod
(17&18) See text
30°
20°
14
13
12
11
9
18
10
8
7
6
5
4
15
16
3
17
1
2

Fig. 3 Front and side views of the Still roller-frame trawl. Side view shown in fishing attitude.



DIMENSIONS

(A) 1.9 cm (3/4") I.D.
(B) 1.1 cm (7/16") Rod
(C) 2.9 cm (1 1/8") I.D.
(D) 1.1 cm (7/16") Rod
(E) 1.2 cm (1/2") Flattened 3/4" I.D. pipe
(F) 9mm (3/8") Half of a chain link
(G) 1.1 cm (7/16") Rod (scrap, 2.5 cm long)
(H) 1.1 cm (7/16") Rod
(I) 1.9 cm (3/4") I.D.
(J) 6.6 cm (2 5/8") Washer, (1/4") stock
(K) 2.5 cm (1") Rod
(L) 7.6 cm (3") I.D.
(M) 2.9 cm (1 1/8") I.D.
(N) 1.2 cm (1/2") I.D.
(O) 1.1 cm (7/16") Rod
(P) 3.5 cm (1 3/8") × (1/4") Washer

Fig. 4 Rear view of roller assembly of the Still trawl showing axle, axle housing, "breaker bar" and roller in an exploded isometric projection.

In Biscayne Bay, the larger double-rigged vessels fishing in about 15 ft (4.6 m) of water use approximately 100 ft (30 m) of 3/8-in galvanized wire towing cable for each net; about 75 to 80 ft (23 to 24 m) of cable are in the water during towing. Because galvanized wire rope rusts, it is standard practice to load the winch drums with 450 to 600 ft (137 to 183 m) of wire cable on each winch drum, cutting off the rusted end portions as needed. Some fishermen use 1/4-in (6 mm) stainless steel cable but this is reported to cut the sheaves of the lifting tackle.

There is no fixed warp-length to depth ratio; differences in the behavior of the shrimp often dictate that the attitude of the net frames be altered, which requires manipulation of warp length. As a rule, vessel speed and warp length are adjusted so that the angle between the warp and the water surface is about 20 to 30°. This causes the net frame to fall forward so that the leading edge of the upper net body (Fig. 5) forms an overhang; this prevents the vertical escape of shrimp flipping off the bottom.

The strainer bars are designed to exclude large objects from the net; sponges, water-logged coconuts, etc. cause damage to the catch if permitted to enter the codend. The spacing and orientation of the strainer bars in relation to the rollers is important. In older versions of the roller-frame trawls, the bars were often spaced approximately 4 in from center to center. The Still trawl has the bars spaced 2 1/8 in center to center. The narrower spacing does not hinder the passage of shrimp into the nets but reduces the amount of trash which is thrown up into the overlying water by the rollers.

The bars have been reported to serve as rakes, stirring the bottom to dislodge shrimp, but this is neither their designed nor their actual function. When viewed from the frame ends, the bars point toward the front edge of the roller axle (Fig. 4). In this position they cannot come in contact with the bottom; on vegetated bottom they may part the grass but they do not damage it or reach the root structures.

The "breaker bar" and associated 7/16-in rod (Fig. 3) forms the point of attachment of the lower edge of the net. The netting is securely laced to the 7/16-in rod. Biscayne Bay nets are made of 1-in streched mesh netting and are tapered to a codend. The nets are 25 ft (7.6 m) long, of which about 8 to 10 ft (2.4 to 3 m) is codend. A lazy line is attached approximately 8 ft forward of the codend tie, and the free end is tied to the inboard side of the trawl frames in easy reach of the deck when the frames are in the raised position. A styrofoam float is attached to a line on the outboard side of each frame and is used to mark the position of the gear should the towing line part while under way.

4.1 Construction features of the trawl frame

In the interest of economy, the Still trawl frames are made of untested galvanized pipe. The axle sleeves in the rollers require tested pipe, however, since any flaws on the inside of these sleeves could cause the rollers to bind and drag rather than roll.

The roller axle and strainer bars should be constructed of cold-rolled steel for durability. Generally, the frame will last one and a half to two times as long as the rollers, so replacement rollers will be needed. To replace the rollers, the axle must be removed. This means that the welds (Fig. 3, point 17), must be accessible for removal. Spot welds on each end securing axle to frame are preferable to bolts passed through holes in the axle ends because vibration causes bolts to wear rapidly, resulting in the loss of one or more rollers. Spot welds can be removed rapidly. The welds should be inspected every 2 or 3 mo to see that they are secure.

The points of contact of the frame members are strengthened by flattening slightly the ends of the pipe to be welded. This is done at all points except at the bottom (Fig. 4, A to C), where the frame attaches to the axle housing. There, the gaps due to the two different pipe sizes are small and can be filled easily by the welder. With frames as large as the one illustrated (Fig. 3), it is necessary to strengthen the frame at these strain points. This is done by welding lengths of 7/16-in rod stock around the pipe sections (Fig. 3, point 18).

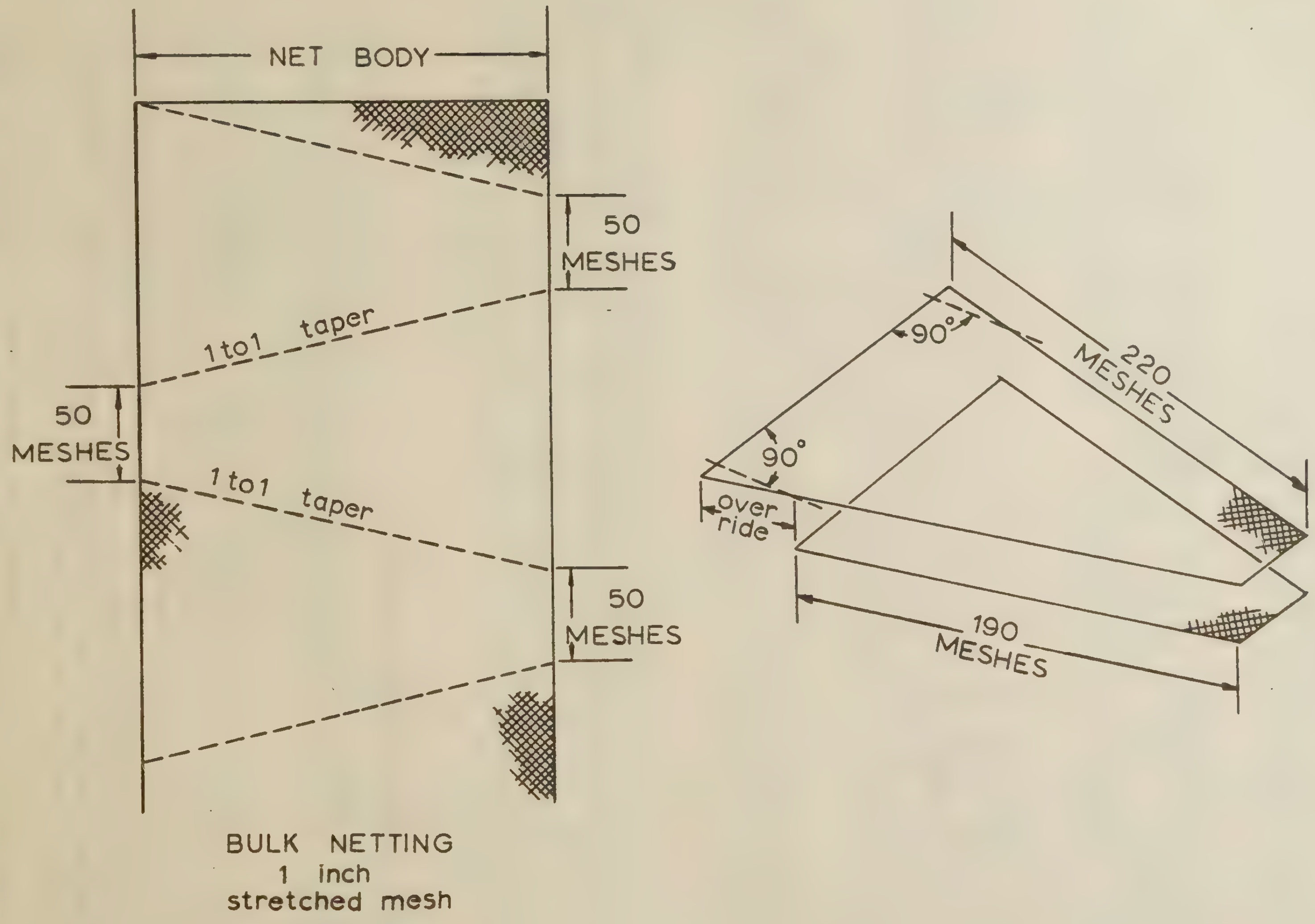

NET BODY
50 MESHES
1 to1 taper
50 MESHES
1 to1 taper
50 MESHES
BULK NETTING
1 inch
stretched mesh
90°
220 MESHES
90°
over ride
190 MESHES

Fig. 5 Top view of the net showing "dovètail" layout, and an isometric projection showing top and bottom prior to sewing.

The frame should be built first without the strainer bars. When strainer bars are added, the frame and cross bar to which the strainer bars are attached will warp from the heat of welding. This can be corrected by placing the completed frame assembly on a flat surface, (with the axle and rollers in place) and applying downward pressure on the frame to re-align it. The free end of the axle can be spot welded then to the end axle housing.

The angle formed by the frame and the breaker bar should be approximately 85° to reduce the amount of bottom debris taken and to increase shrimp catch. The clearance between the breaker bar and the rollers is also important. It should be no more than 5/8 in to keep shrimp from "skipping" under the net. Half of a 3/8 in chain link is welded to the underside of the breaker bar (Fig. 4, point F) at each end. These are for attachment of lines which are incorporated in the net as described below.

The net is made of 1-in stretched mesh nylon or dacron bulk netting. The top panel is 220 meshes long and the bottom panel is 190 meshes long. Several net panels are cut from a single piece of bulk netting on a one-to-one taper starting from one end. Then, 50 meshes are counted before the second cut is made (Fig. 5). The second cut is made on an expanding one-to-one taper. By "dove-tailing" pieces in this fashion there is a minimum of wasted material.

With the 220-mesh top panel on top of the 190-mesh bottom panel, the seams are sewn securely. The top forward 30 meshes form an over-hang. A straight cut at 90° (right angle) is made across the 30-mesh top or over-hang to form the sides, which should be securely laced to the breaker bar support rod (Fig. 4, point D). A lightly greased length of polyethylene line is woven along the leading edge of the net mouth to help prevent wear by sand and shell debris. This line also distributes the load over the entire leading edge of the net.

Two- to three-foot lengths of polyethylene line are woven into the seams in the net, one on each side, about one foot from the leading edge of the net. These lines are fastened to the half-link of 3/8-in chain on the breaker bar by a 1/4-in shackle and help remove slack in the net when securely tied.

Two styrofoam floats are attached to the top of the net about 1 to 2 ft (0.3 to 0.6 m) from the codend tie. These elevate the codend and prevent its snagging on the bottom.

5 HANDLING THE CATCH

The catch containing fish, shrimp, plant fragments and other extraneous material is removed from the nets as quickly as possible to avoid harming the shrimp. The catch is sorted on tables mounted to the edge of live boxes provided with circulating sea water. In most cases the sorting tables have raised sides, 4 to 5 in high, with the outboard ends removable. The tables are constructed so that there is a slight slope toward the outboard end. The open end of the tables and the slope, permit crabs and active fish to "sort themselves". Many drags have almost no trash and are put in the bait tanks after a quick inspection for fish and crabs. If quantities of grass fragments are collected, they are removed completely to avoid the danger of clogging the pump intakes. At such times, the sorting is done rapidly and the fish and animals, other than shrimp, are returned to the bay before the shrimp are placed in the tanks. Observations of catch taken in each of 22 pairs of drags, containing between 6 and 34 lb (2.7 and 15.4 kg) of shrimp, fish and extraneous material, indicated that an average of only 4 1/2 min was required to sort each net haul.

Most shrimp recover quickly from sorting and are lively and ready for marketing the following morning. Most fish also survive this handling. Atlantic thread herring, Ophisthonema oglinum, and sardines, Harengula pensacolae, usually survived if not damaged by crabs or by gilling in the trawl meshes. Snappers and other bay species appeared to suffer no ill effects from the brief exposure. The short drags and sorting time, the small amounts of trash and the moist night air, usually prevent the fish from being severely damaged. Only one species, the blackcheek tongue sole, Symphurus plagiusa, was commonly killed by being gilled in the meshes of the trawl.

6 THE CATCH

The quantities of fish, invertebrates and plant material taken in a series of 22 paired drags with 12-ft roller-frame trawls on grassy bottom in Biscayne Bay are shown (Table II). The towing time per drag was about 15 min in 16 ft (5 m) of water.

TABLE II

Quantities of fish, invertebrates and plant material in 44 trawl hauls. Weights are totals for two nets and are in pounds

Drag No.	Number of nets	Weight of plants	Weight of fish	Weight of invertebrates	Total weight per drag
1	2	0	1.25	29.00	30.25
2	2	0	2.00	32.00	34.00
3	2	.5	1.50	25.00	27.00
4	2	1.0	1.50	22.00	25.00
5	2	0	2.00	32.00	34.00
6	2	1.0	1.50	26.00	28.50
7	2	1.0	1.00	17.00	19.00
8	2	2.0	2.50	16.50	21.00
9	2	1.0	2.00	18.00	21.00
10	2	0	1.00	28.50	30.50
11	2	.5	1.50	19.00	21.00
12	2	2.0	1.00	19.50	22.50
13	2	1.5	1.00	31.50	34.00
14	2	0	1.75	5.00	6.75
15	2	0	3.50	11.00	14.50
16	2	0	2.00	8.50	10.50
17	2	27.0	3.00	2.50	32.50
18	2	.3	2.75	3.00	6.00
19	2	3.5	1.00	1.75	6.25
20	2	0	2.50	9.25	11.75
21	2	0	1.75	11.50	13.25
22	2	0	2.00	10.50	12.50
Averages		3.4	1.80	17.20	21.00

Fish catches ranged from 1.0 to 3.5 lb (0.5 to 1.6 kg) per pair of drags, with the average just over 1.75 lb (0.7 kg). The fish were small. As many as 20 species were represented in some drags. Table III presents a list of the species taken and the number of each as a percentage of the total catch from all 22 drags with paired trawls. Size ranges have been included. Only three of the species, the yellowtail snapper, *Ocyurus chrysurus*, the gray snapper, *Lutjanus griseus*, and the Lane snapper, *Lutjanus synagris*, are considered game fishes. The total catch of these three species was 31 individuals of 1,541 fish, or 2 percent. There were 5 pan fish species, (i.e., fishes sometimes kept by anglers for eating but not normally regarded as gamefish). There were white grunt, *Haemulon plumieri*, bluestripe grunt, *Haemulon sciurus*, mojarras, *Eucinostomus* sp., pigfish, *Orthopristis chrysopterus*, and sand perch, *Diplectrum formosum*. These amounted to 16 percent of the total.

TABLE III

List of species of fishes taken in 44 roller-frame trawl drags expressed as per cent of total number of fishes. Size range is given in inches total length

Common Name	Scientific Name	No.	Per cent	Total L.in.
Blackedge moray	*Gymnothorax nigromarginatus*	2	.13	4
Hogfish	*Lachnolaimus maximus*	1	.06	4
Leopard searobin	*Prionotus scitulus*	8	.52	4-8
Blustripe grunt	*Haemulon sciurus*	19	1.23	2-6
Bandtail puffer	*Sphaeroides spengleri*	5	.32	2-3
Inshore lizardfish	*Synodus foetans*	1	.06	8
Sand perch	*Diplectrum formosum*	55	3.56	3-8
Pinfish	*Lagodon rhomboides*	36	2.33	3-6
Dusky pipefish	*Synagnathus floridae*	5	.32	6-8
Spotted seahorse	*Hippocampus erectus*	18	1.16	2-4
Striped burrfish	*Chilomycterus schoepfii*	82	5.32	3-8
Hogckoker	*Trinectes maculatus*	15	.97	4
Yellowtail snapper	*Ocyurus chrysurus*	2	.13	3
Redfin parrotfish	*Sparisoma rubripinne*	182	11.81	2-7
Gray snapper	*Lutjanus griseus*	7	.45	2-3
Lane snapper	*Lutjanus synagris*	22	1.42	3-4
Cowfish	*Lactophrys quadricornis*	158	10.25	1-8
Barbfish	*Scorpaena brasiliensis*	63	4.08	2-8
Planehead filefish	*Monacanthus hispidus*	16	1.03	1-3
Fringed filefish	*Monacanthus ciliatus*	490	31.79	1-4
Gulf toadfish	*Opsanus beta*	172	11.16	2-10
White grunt	*Haemulon plumieri*	146	9.47	2-5
Mojarras	*Eucinostomus* spp.	25	1.62	2-5
Spotfin flounder	*Citharichthys spilopterus*	2	.13	4-5
Pigfish	*Orthopristis chrysopterus*	3	.19	3-8
Eyed flounder	*Bothus ocellatus*	1	.06	3
Cardinal fish	*Apogon* sp.	4	.25	3
		1,541		

7 DISCUSSION

The roller-trawl is the major fishing gear of the modern live bait shrimp fishery of Florida. Over the years, it has undergone considerable modification, chiefly to reduce weight and to produce large catches of shrimp with as little "trash" as possible. The Still trawl described here is the most advanced design in the industry, to our knowledge, and has been stripped of all but the essentials, such as rollers, strainer bars and breaker bar. Its light weight, low cost, and ease of fishing should make it adaptable in many estuarine areas of the world, particularly in the tropics, where large shrimp resources may exist but which are not now being exploited. It can operate in less than 6 ft of water and by suitable reduction in size can be adapted to small boats.

The gear may also be useful as a quantitative sampler. By the addition of a meter to record revolutions of the roller, the length of the towing track can be measured.

The design features have been developed with the assistance of fishery biologists and ecologists and it is believed that the gear does no significant damage to the biota of the estuaries.

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MICROSPORIDOSIS IN COMMERCIAL PENAEID SHRIMP [1]

by

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Abstract

Several species of Microsporida are present in the musculature of commercial penaeid shrimp. Although these parasites do not harm humans they reduce the quality of processed shrimp and perhaps cause epidemics in nature. Some species of Microsporida are known to occur in shrimp but have not been identified. Also fundamental knowledge about the intensity and incidence of infection and mechanics of transmission of these parasites is lacking. If this information were obtained, possibly fluctuations in abundance of shrimp stocks could be more clearly explained, the quality of shrimp improved, and shrimp farming could be placed on a more solid footing.

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E/68

LES MICROSPORIDOSES DES PENAEIDAE D'INTERET COMMERCIAL

Resumé

Plusieurs espèces de Microsporida sont présentes dans la musculature des Penaeidae d'intérêt commercial. Ces parasites ne sont pas nocifs pour l'homme, mais ils font baisser la qualité des crevettes après traitement industriel et causent peut-être des épidémies dans les stocks. On connaît l'existence d'un certain nombre d'espèces de Microsporida de la crevette, mais elles n'ont pas été identifiées. On manque également de renseignements de base sur l'intensité et l'incidence de l'infection et le mécanisme de transmission de ces parasites. Peut-être serait-il possible, si l'on parvenait à obtenir ces informations, d'expliquer plus clairement les fluctuations quantitatives des stocks de crevettes, d'améliorer la qualité de celles-ci et d'assurer une plus grande stabilité aux élevages.

MICROSPORIDIOSIS EN LOS CAMARONES PENEIDOS COMERCIALES

Extracto

En el tejido muscular de los camarones peneidos comerciales existen varias especies de microsporidios. Aunque estos parásitos no perjudican al hombre rebajan la calidad de los camarones elaborados y tal vez causan epidemias. Se sabe que en los camarones existen algunas especies de microsporidios pero éstas no han sido identificadas. Faltan igualmente conocimientos precisos sobre la intensidad e incidencia de la infección y del modo de transmitirse estos parásitos. Si pudiera obtenerse esta información, posiblemente se explicarían con más claridad las fluctuaciones que se registran en la abundancia de las poblaciones de camarones, se mejoraría la calidad de éstas y se podría establecer su cultivo sobre una base más sólida.

1 INTRODUCTION

Since the early fifties shrimp has been the most valuable marine resource of the United States, surpassing tuna and salmon. In addition to domestic production, which reached over 234 million lb (106,000 t) in 1966, shrimp have been imported from foreign countries in sharply increasing quantities in recent years; in 1966 over 178 million lb (80,740 t) were imported. The pink shrimp, Penaeus duorarum Burkenroad supports the most valuable commercial fishery in Florida. During 1966 over 20 million lb (9,070 t) of pink shrimp tails, valued in excess of $8.5 million to fishermen, were landed from the Tortugas grounds alone. Even a small proportionate loss of this catch through the discard of parasitized shrimp produces a considerable economic loss because of the high unit value of the catch.

Because penaeid shrimp are farmed in many areas of the world and are being considered for farming in southeastern United States, research on diseases should keep pace with study of the other aspects of the biology of these valuable crustaceans.

2 MICROSPORIDIAN SPECIES

Eight species of parasites are known from the pink shrimp (Eldred et al., 1961). Nearly all occur in the cephalothorax which is discarded before the shrimp is marketed. Many Microsporida occur in all organs of the body and the tail muscles. This report discusses the occurrence of microsporidian species which invade mainly tail muscles; these Microsporida cause a reduction in shrimp quality.

Several species of Microsporida cause infections in commercial shrimp. In Louisiana the brown shrimp, P. aztecus, is infected with Nosema nelsoni, and the white shrimp, P. setiferus, with Thelohania penaei (Sprague, 1950). In Florida the pink shrimp, P. duorarum, and the Caribbean brown shrimp, P. brasiliensis are infected with T. duorara (Iversen and Manning, 1959; Iversen and Van Meter, 1964). Mr. J. Ewald, Instituto Venezolano de Investigaciones Cientificas, who is studying the biology of the South American white shrimp, P. schmitti, in the Lake of Maracaibo, Venezuela, has observed discolouration of the tails of this species. In preserved whole shrimp and sections provided by Mr. Ewald, I have found spores, probably of a Microsporida. Mr. Harvey Bullis, U.S. Fish and Wildlife Service, has observed whitish or chalkish colouration in royal red shrimp, Hymenopenaeus robustus, from the Gulf of Mexico. He kindly sent me specimens of the royal red shrimp which contained spore-like bodies similar to known Miscrosporida. Microsporida have not been reported from P. schmitti or H. robustus nor described in the literature.

Microsporidian species in penaeid shrimp are not known to be harmful to man, but degradation of quality and the consequent economic loss by reason of their presence in commercial shrimp is of concern.

3 LIFE CYCLE

When an infected shrimp dies or molts the microsporidian spores are released into the water and ingested by other shrimp as they feed. It is generally believed that there are no intermediate hosts in the life cycle. The cannibalistic behaviour of shrimp would favour transmission of this parasite. Once in the digestive tract of a host, the polar filament inside the spore is released, and probably anchors the parasite to the gut wall. The sporoplasm emerges from the spore case as a small amoebulae which enters the blood stream of the shrimp and reaches the sites of infection. There, large numbers of spores are produced during sporulation. The host tissue reacts with extensive hypertrophy of the cytoplasmic body and nuclei. When the infection is heavy the musculature of the shrimp becomes whitish and opaque. This white pus-like material is formed by the liquification of muscles and the breakdown of spore-forming bodies during sporulation. Shrimp, so heavily infected that muscle fibres are completely infiltrated with the parasite, are of poor quality, and the postmortem breakdown of their tissues is rapid. This condition is familiar to fishermen who call these heavily infected shrimp "milk" or "cotton" shrimp. Fishermen discard them from the catch because their appearance is unattractive, and the muscle is soft and has poor texture. It is not known whether the quality degradation produced by this parasite impairs the keeping quality of shrimp.

4 EFFECT ON QUALITY OF HOST FLESH

There are numerous reports of adverse effects on the quality of flesh of commercial fish caused by histozoic Myxosporida which are related closely to Microsporida. The barracouta, _Thyrsites atun_, of commercial importance in both Australia and South Africa, is infected with a histozoic myxosporidian species, _Chloromyxum thyrsites_. Willis (1949) working on barracouta in Australia reports that "... from a few to twenty-four hours after capture the flesh softens and finally disintegrates into a thick, viscuous mass." Such infected fish are called "milky barracouta".

These accounts and many others leave little doubt that the Microsporida and Myxosporida are destructive to host tissue in many areas throughout the world and that, although proper handling procedures of fresh fish are followed in infected fish, a considerable reduction in quality begins soon after death of the fish.

5 INCIDENCE OF MICROSPORIDIOSIS

There are available some estimates of the incidence of infection of pink shrimp based on heavily infected specimens which fishermen and fish dealers recognize as "cotton shrimp" (Woodburn _et al_., 1957; Hutton _et al_, 1959; Kruse, 1959). These observations suggest a light incidence of infection, but the estimates are low since no systematic, careful search has ever been made, and only the obviously infected shrimp can be detected without careful scrutiny. In northern Florida, Kruse (1959) found about 2 percent of the pink shrimp he examined microscopically to be infected with these parasites. His samples included only young shrimp. In general there is a tendency for the incidence of infection of parasites to increase with the age of the host (Noble, 1960). Because some Myxosporida exhibit seasonal changes in intensity of infection (Noble, 1957), data to determine incidence must be gathered throughout the year. Seasonal data on incidence of Microsporida have not been gathered for shrimp.

Microsporidian species have caused epidemics among marine animals and there are indications from the high intensities of infection and serious pathological changes in infected aquatic animals that epizootics could take place although undetected due to predation. For example, Viosca (1943) noted that about 90 percent of the ovaries of the white shrimp were infected with a microsporidian species in Louisiana. In another study, Haley (1953) found that about 23 percent of the smelt _Osmerus mordax_ from the Great Bay region of New Hampshire were infected with the microsporidian species _Glugea hertwigi_. He concluded that the serious "pathological manifestations" of the disease caused by cysts covering the pyloric caeca, liver, gonads, and swim bladder suggest that it is a serious factor in the decline of the smelt population in that area. A myxosporidian species is known to invade "from 40 percent to 90 percent of the populations" of four species of commercial fish in South Africa (Rowan, 1956). In one species alone about 25 percent of the catch was unsuitable for the market due to this histozoic parasite.

6 INTENSITY OF INFECTION

There is no information on the average infection by Microsporida of individual pink shrimp. Light infections have been noted (Kruse, 1959) as well as shrimp completely infiltrated with this parasite. Rowan (1956) found spore counts of a myxosporidian species ranging from "tens of thousands" to "tens of millions per gram" of fish flesh in some South African fishes.

Some general external characteristics of heavily infected pink shrimp are obvious, but medium to light infections are not described. In heavy infections the shrimp becomes whitish, and may show blue-black areas of the exoskeleton. Early and light infections apparently require microscopic examination.

The means by which Microsporida are transmitted from shrimp to shrimp are unknown. Experiments involving feeding healthy pink shrimp with pieces of shrimp infected with Thelohania duorara at the Institute of Marine Sciences were unsuccessful in transmitting the disease. This failure together with other similar ones illustrates our lack of knowledge of the life cycles of Microsporida.

7 ANSWERS REQUIRED

For many of our valuable commercial species of fishes including tunas, salmon and herring, the important parasites have been identified, and for some species the incidence and intensity of infection have been determined. The commercial value of these fish species individually is below that of the commercial penaeid shrimp, yet for the shrimp similar studies have not been made. Studies are required to provide knowledge of the mechanics of infection of Microsporida and of the importance of these parasites in causing population fluctuations. Research should be designed to produce answers to these questions:

1. What is the incidence of microsporidian infection of penaeid shrimp in nature at different times of the year and for different sizes of shrimp? Are these rates sufficiently high to be of concern to the shrimp industry in terms of quality loss? Is the intensity of infection sufficiently high to suggest that population fluctuations may be influenced by these parasites?

2. Are there certain times of the year or places on the fishing grounds where heavily infected shrimp occur, and can fishermen avoid them?

3. Are there any clearly recognizable external characteristics which permit culling of infected shrimp at various intensities of infection to prevent them from reaching the consumer?

4. At what size (age) do shrimp first become infected?

5. How are infections transmitted from shrimp to shrimp? Are there immediate hosts in the life cycles?

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POSIBILIDADES PARA INCREMENTAR LA PRODUCCION CAMARONERA DE ALTA MAR EN LAS AGUAS DEL OCEANO PACIFICO FRENTE A MEXICO

por

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Extracto

Se alude a la importancia de la información derivada de las expediciones biológicas para el mejor conocimiento y valoración de las industrias pesqueras, haciéndose un relato de las exploraciones y expediciones pesqueras más conocidas para la pesca de camarones en el litoral mexicano del Pacífico, y en el Golfo de México, con la localización de nuevas áreas de pesca y producción estacional de camarones así como el conocimiento de áreas susceptibles de ser pescadas a profundidades mayores. Incluye también algunas notas relativas a la descripción de las especies de camarones comerciales capturadas en esas expediciones. Describe lo relacionado con el descubrimiento del camarón rosado (*Penaeus duorarum*) en el Golfo de México así como el camarón cristalino (*Penaeus brevirostris*) en las costas del Pacífico; señala la necesidad de que se lleven a cabo estudios científicos para el mejor aprovechamiento de nuevos recursos camaroneros en las costas occidentales de México. Se destaca la importancia de las planificaciones y programas para la obtención de datos que tiendan a incrementar los conocimientos sobre la disponibilidad de los efectivos comerciales de peneidos.

E

POSSIBILITIES OF INCREASING LANDINGS OF SHRIMPS AND PRAWNS BY DEEP SEA VESSELS OFF THE PACIFIC COAST OF MEXICO

Abstract

Reference is made to the importance of information derived from biological expeditions for a better understanding and appraisal of the fishing industries. An account is given of the best known shrimp fishery explorations and expeditions along the Pacific Coast of Mexico and in the Gulf of Mexico with the location of new fishing grounds, figures on seasonal production of shrimps and prawns, and information on areas where fishing at greater depths is practical. Descriptive notes on commercial shrimps species obtained during these expeditions are also given. The discovery of the pink shrimp (*Penaeus duorarum*) in the Gulf of México and of "camarón cristalino" (*Penaeus brevirostris*) on the Pacific Coast is recounted. The need for scientific research in order to obtain a better exploitation of new shrimping grounds along the west coast of Mexico is indicated. Finally, the stress is laid on the importance of planning and scheduling of data collection to ascertain the availibility of commercial stocks of edible penaeid shrimps.

POSSIBILITES D'AUGMENTER LA PRODUCTION DE CREVETTES DE HAUTE MER DANS L'OCEAN PACIFIQUE AU LARGE DU MEXIQUE

Résumé

L'auteur, signalant l'importance des renseignements fournis par les expéditions biologiques pour approfondir les connaissances sur les industries halieutiques et pour en faciliter l'évaluation, rend compte des explorations et expéditions les plus connues de pêche de la crevette sur les côtes mexicaines de l'océan Pacifique et dans le golfe du Mexique, donnant des précisions sur de nouvelles aires de pêche et la production saisonnière de crevettes, ainsi que sur l'existence de zones où la pêche est possible à de plus grandes profondeurs. Il fournit également quelques notes décrivant les espèces de crevettes d'intérêt commercial capturées pendant ces expéditions. L'auteur signale la découverte de *Penaeus duorarum* dans le golfe du Mexique et celle de *Penaeus brevirostris* sur le côte du Pacifique, fait valoir la nécessite d'effectuer des études scientifiques afin de mieux utiliser les ressources crevettières nouvelles des côtes occidentales du Mexique. Enfin, il souligne l'importance des plans et programmes visant à obtenir des données susceptibles d'accroître les connaissances sur la disponibilité des stocks de Penaeidae présentant un intérêt du point de vue commercial.

1 INTRODUCCION

Es indudable el valor que tiene para nuestra industria pesquera en general, la información que nos brindan los informes de las grandes expediciones biológicas, a continuación de las cuales deben realizarse los trabajos de ponderación económica de las especies de valor comercial.

No se debería efectuar ningún trabajo científico sin hacer previamente un examen minucioso de los trabajos realizados hasta ahora, por lo que se deberían continuar los estudios científicos y efectuar asimismo exploraciones con fines comerciales e industriales haciendo uso de los estudios científicos previos.

2 EXPLORACIONES EN EL GOLFO DE MEXICO Y COSTA ATLANTICA DE AMERICA

Las exploraciones más conocidas que recientemente se llevaron a cabo en la costa atlántica de América con el fin de localizar concentraciones comerciales de camarón (véase Cuadro 1) son buen ejemplo para la planeación del desarrollo pesquero en las aguas del Océano Pacífico, frente a México.

La expedición mexicana-japonesa, que trabajó en el Golfo de México entre los años 1936 a 1937 (mientras otros barcos nipones capturaban enormes cantidades de camarón en la costa nordoccidental de México), permitió localizar el camarón rosado (Penaeus duorarum) en la zona de Campeche, determinando, grosso modo, la región de la plataforma continental de México como habitat de esta especie donde actualmente se captura.

Los primeros viajes exploratorios del B/I Oregon en el Golfo de México, iniciados en 1950, permitieron descubrir nuevos fondos de pesca del camarón café (Penaeus aztecus) y localizar áreas de mayor abundancia y sus límites geográficos entre los meridianos 91° y 95° long. O y las líneas batimétricas de 35 a 50 brazas (64 a 91 m) frente a las costas de Louisiana y Texas. Posteriormente un barco explorador localizó una mejor área de abundancia de camarón café entre los meridianos 88° y 90° long. O, a ambos lados del delta del Mississippi con lances de hasta 2.700 libras/h (1.225 kg/h) de camarón café gigante. Una vez conocida la abundancia en esa área la flota pesquera de los Estados Unidos de América inició inmediatamente su explotación.

Más tarde, los investigadores del B/I Oregón precisaron que la distribución del camarón café alcanzaba las costas de Texas, al oeste, y hasta Ciudad del Carmen, Campeche, al sur.

También se encontraron extensas zonas de pesca de camarón rojo (Hymenopenaeus robustus) a profundidades de 350 a 375 brazas (640 a 686 m) entre Dry Tortugas y Aransas Pass.

El B/I Antillas, al realizar una campaña de pesca exploratoria en colaboración con el U.S. Fish and Wildlife Service , localizó el mencionado camarón rojo, conocido vulgarmente como camarón "Royal Red" a 100 millas (185 km) al este del Mississippi, en la línea de 200 brazas (366 m).

Las expediciones de los barcos pesqueros Pelican, Combat y Silver Bay, durante los años de 1956 a 1958, descubrieron nuevas concentraciones de camarón rojo entre Cabo Hateras y Dry Tortugas a una profundidad de 180 a 200 brazas (330-366 m) alcanzando las capturas comerciales hasta 800 libras (363 kg) por día en el mar, situando los lugares de mayores capturas en el área comprendida entre San Agustín y Cabo Cañaveral.

Las posteriores exploraciones del B/I Oregon, en los años 1957 y 1958 en la costa noreste de Sudamérica, dieron origen a la importante industria pesquera de las Guayanas. Las recientes exploraciones llevadas a cabo en las costas del Mar Caribe, de Colombia y Venezuela, son también de gran interés para el desarrollo pesquero de estos países y las Pequeñas Antillas.

Las exploraciones anteriormente citadas tuvieron dos objetivos principales:

(i) Descubrir nuevos fondos de pesca camaronera, determinar la productividad estacional de las especies ya conocidas por los pescadores y experimentar los artes más adecuados para su captura;

(ii) Llegar a conocer la importancia económica de otras especies de camarón, principalmente las de profundidad, concentrando la atención en aquéllas cuya descripción ya se conocía y que son el producto de esfuerzos científicos desarrollados anteriormente.

El primer objetivo se logró en varias ocasiones, dándose por terminada la pesca exploratoria debido al arribo de gran número de barcos pesqueros que se enteraron de la localización de los nuevos bancos camaroneros, reportados para su explotación por las embarcaciones investigadoras.

El segundo objetivo, alcanzado con mayor esfuerzo, por la amplitud de la zona a explorar, permitió a la flota pesquera contar con un área de pesca vírgen muy extensa, en la que se comprobó que habitan cantidades importantes de varias especies de camarón. Los datos científico-biológicos se publicaron en la Memoria del Museo de Zoología Comparada del Colegio de Harvard, en la que se dan los resultados de los muestreos realizados mediante rastreos en el Golfo de México (1877-1878), en el Mar Caribe (1878-1879) y a lo largo de la costa atlántica de los Estados Unidos (1880), llevados a cabo por el B/I _Blake_ bajo la supervisión de Alexander Agassiz. Estos datos se refieren a las especies: _Hymenopenaeus_ _robustus_ Smith, _Plesiopenaeus_ _edwardsianus_ (Johnson), _Penaeopsis_ _megalops_ (Smith) y _Penaeus_ _brasiliensis_ Latreille.

CUADRO I

Exploraciones en el Golfo de México y costa atlántica de América

Institución	Barco	Años	Zona
Nippon Suisan Kabuskiki Kaisha Co.	_Japonés_	1936-37	Golfo de México
U.S. Branch of Commercial Fisheries	_Oregon_	1950-54	Golfo de México
Gibbs Corp. y U.S. Commercial Fisheries	_Antillas_	1952	Golfo de México
U.S. Bureau of Commercial Fisheries	_Pelican_	1956-58	Costa atlántica del sur de los Estados Unidos
U.S. Bureau of Commercial Fisheries	_Combat_	1956-58	Costa atlántica del Sur de los EUA y proximidades de las Bahamas
U.S. Bureau of Commercial Fisheries	_Silver Bay_	1956-58	Costa atlántica de la Florida
U.S. Bureau of Commercial Fisheries	_Oregon_	1957-58	Noreste de Sudamérica

3 ACTIVIDADES PESQUERAS Y EXPLORATORIAS SOBRE LA PESCA CAMARONERA EN LA COSTA MEXICANA DEL PACIFICO

3.1 Camarón azul y blanco

En la costa del Pacífico de México, se capturan camarones para fines comerciales con embarcaciones pesqueras de altamar, desde el año de 1934. Desde dicho año hasta 1953, por razones de mercado sólo se capturaron el camarón azul (Penaeus stylirostris) y el camarón blanco (Penaeus vannamei). La localización de estas dos especies se llevó a cabo en el año 1936 por los siguientes cruceros:

(i) La exploración del Minato-Maru en las costas de Sonora, Sinaloa y Narayit, durante los meses de enero, febrero y marzo, situó los bancos camaroneros que hasta la fecha son todavía explotados;

(ii) Las exploraciones del Minato-Marú y del Sapporo-Marú realizadas en las costas de Colima, Michoacán, Guerrero, Oaxaca y Chiapas.

Los resultados de estas únicas exploraciones organizadas con fines de explotación comercial, no fueron dados a conocer a nuestro país en toda su magnitud por lo que el desarrollo de la pesca de altamar fue lento con respecto a estas dos especies, dejándose al esfuerzo y riesgo del pescador mexicano el reconocimiento de nuevas zonas pesqueras.

Sin embargo, recordamos la ayuda que prestó a la flota pesquera-camaronera del Pacífico, el barco pesquero congelador Mahoning, al mando del Capitán A. Cortés Acosta, que en forma privada realizó expediciones de importancia en los años que van desde 1949 a 1958 en el Golfo de Tehuantepec. En este período se demostró la costeabilidad de la pesca de camarón café y blanco, en Chiapas y Oaxaca. La mencionada embarcación sirvió a la vez de barco nodriza a la flota pesquera que llevó de compañía mientras se ponían las bases a la importante estructura pesquera con que cuenta ahora el Puerto de Salina Cruz, Oaxaca.

En el año 1951, el personal del Mahoning, durante su viaje de regreso del Golfo de Tehuantepec, descubrió la zona pesquera de camarón azul en la costa occidental de Baja California.

3.2 Camarón café

Las capturas con fines comerciales de camarón café (Penaeus californiensis) datan desde 1953 en la costa del Pacífico de México.

Si la exploración de las zonas pesqueras de camarón blanco y azul costó un gran esfuerzo a la flota del Pacífico, el camarón café, debido a la amplitud de la zona de distribución sobre la plataforma continental, ha requerido esfuerzos superiores para capturarlo, pudiéndose afirmar que aún falta completar estudios científico-biológicos de esta especie necesitándose exploración en la costa occidental de Baja California, en donde no se conoce con exactitud la distribución estacional y batimétrica de este crustáceo, especialmente de Punta Concepción al norte.

3.3 Camarón rosado o cristalino

El camarón cristalino (Penaeus brevirostris) se comenzó a capturar a partir de 1954, si bien su potencial pesquero había sido ya señalado por el B/I Sharon del Instituto Biológico del Pacífico.

Sobre este camarón faltan todavía estudios científico-biológicos y exploratorios en la zona de su distribución en México (de Sinaloa a Chiapas).

Con lo anteriormente escrito, exponemos brevemente las necesidades de estudios y exploraciones sistemáticas de algunas especies comerciales de camarón que se capturan en la actualidad en la costa mexicana del Pacífico, señalando además, que hasta la fecha no ha habido ninguna ayuda oficial en lo que se refiere al mejoramiento de las técnicas y equipos pesqueros, cuya orientación podrá ser de gran beneficio para incrementar la productividad pesquera.

4 ESTUDIO CIENTIFICO PARA EL APROVECHAMIENTO DE NUEVOS RECURSOS CAMARONEROS EN LA COSTA MEXICANA DEL PACIFICO

Existen trabajos científico-taxonómicos y de zoogeografía de la zona panámica del Pacífico, dentro de la cual está considerada gran parte de nuestra plataforma y mar adyacente.

Los estudios a que nos referimos, señalan la existencia de varias especies de camarón y cangrejos que posiblemente tienen importancia para nuestra industria pesquera, entre las cuales citamos el camarón Solenocera agassizii Faxon, descrito en el informe de la expedición del Albatros contenido en la Memoria del Museo de Zoología Comparada del Colegio de Harvard de 1895. Este camarón fue encontrado durante la expedición del Albatros en el Golfo de Panamá, en el mes de marzo de 1891, en las estaciones 3389 y 3391 del citado crucero, en profundidades de 153 y 210 brazas (280 y 384 m) respectivamente.

Recientemente hemos sabido que el Instituto Nacional Pesquero (debe tratarse del Instituto Pesquero Ecuatoriano) ha encontrado una importante concentración de camarón gigante "Royal Red" en la República del Ecuador, en una profundidad de 273 brazas (500 m) (Anon., 1966). No dudamos que esta concentración esté formada por la especie Solenocera agassizii[1], cuya captura podría dar orígen a un nuevo tipo de barco pesquero-camaronero y a la modificación de los artes pesqueros actuales. Estos cambios podrían también beneficiar a todos los países de la zona panámica entre ellos México, quién, estando a la vanguardia de la pesca camaronera de América Latina, debe conducir las exploraciones a la profundidad necesaria con la probabilidad de localizar también concentraciones de cangrejos gigantes de importancia comercial que eventualmente hayan sido atrapados con las redes de la flota camaronera, en profundidades de 60 a 70 brazas (110 a 128 m) entre Mazatlán y la Isla del Tiburón. De esta manera se diversificará la actividad pesquera, perteneciendo estos crustáceos a los géneros: Paralomis, Lithodes y Paralithodes de los cuales algunas especies se capturan en grandes cantidades en los mares fríos y otras son propias de la profundidad del océano en la región de los trópicos. Hemos ratificado su existencia frente a México, a través de una comunicación personal con el Sr. R. H. Parker, Biólogo del "Marine Biological Laboratory de Woods Hole", Massachusetts, quien ha estudiado en nuestro país la distribución de los macro-invertebrados bentónicos informándonos que:"... existe sobre la pendiente de la plataforma, entre Mazatlán y Guaymas, una enorme población de Paralomis multispina la cuál es una especie de menor tamaño pero muy parecida al cangrejo de Alaska (King Crab) entre profundidades de 400 a 750 m, lográndose capturas de 250 kg en 20 minutos de arrastre, con una red de prueba de sólo 3 m, pescando a la vez en tales profundidades muchos camarones de gran talla".

Independientemente de que nuestro país lleve a cabo las exploraciones que anteriormente recomendamos, es necesario destinar un barco, o los que sean necesarios, para probar la utilidad de distintos equipos para la localización de los camarones y cangrejos gigantes y los artes adecuados para hacer más eficientes las capturas generales de nuestra flota, con el fín de mejorar el nivel económico actual de la industria pesquera nacional.

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[1] Probablemente Solenocera florea. Editor

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METHODS OF MARKING SHRIMP [1]

by

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Abstract

Methods of staining and tagging shrimp are reviewed. Marking methods discussed are staining by injection, feeding, and immersion, and tagging with internal and external tags. Some aids for handling and releasing live shrimp are also discussed.

METHODES DE MARQUAGE DES CREVETTES

Resumé

Etude du marquage des crevettes par coloration (injection, ingestion et immersion) et l'utilisation de marques internes ou externes. Quelques dispositifs pour manipuler ou relâcher les crevettes vivantes sont également examinés.

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[1] Contribution No. 256, Bureau of Commercial Fisheries, Biological Laboratory, Galveston, Texas 77550, U.S.A.

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METODOS DE MARCADO DE CAMARONES

Extracto

Se pasa reseña de los métodos de coloración y marcado de camarones. Los métodos de marcado discutidos, son los siguientes: coloración por medio de inyección, alimentación e inmersión, así como marcado con marcas internas y externas. Se discuten también los modos más aptos para la manipulación y liberación del camarón vivo.

1 INTRODUCTION

Several authors have recently reviewed tagging methods used for fish and crustaceans (George, 1967; Rounsefell, 1963; and Arnold, 1966). A number of methods of marking crustaceans have been tested but few are truly satisfactory. The attachment of tags or the injection of foreign materials usually has some undesirable effects.

The problems are numerous in the search for a satisfactory method of marking shrimp. Methods developed for fish usually are not effective for shrimp because of the small size of shrimp, the periodic shedding of the exoskeleton, and the commercial methods of handling and processing shrimp.

The most satisfactory methods of staining, tagging, and handling shrimp are discussed in this paper.

2 STAINING BY INJECTION

2.1 Development of staining methods

Methods of staining shrimp used first by Menzel (1955) have been refined by several other workers. Dawson (1957) experimented with 26 biological stains as marking agents administered by injection, feeding, and immersion. Costello (1959) injected into shrimp solutions of 65 stains and inks to test their effectiveness as marking agents. Costello and Allen (1961) compared mortality due to predation on stained and unmarked shrimp. They concluded that stained and unstained shrimp were equally vulnerable to predation. Costello (1964) discussed staining techniques, and Klima (1965) evaluated combinations of several different marks. The techniques for staining shrimp by injection have evolved with the accumulation of experience gained from numerous mark-recapture experiments.

When a biological stain is injected into a shrimp, it accumulates and is retained in the gills (a photograph of a stained shrimp is presented in Fig. 1). If the correct amount of stain is used, it is visible only in the gills about 24 h after staining.

The natural coloring of shrimp either before or after death must be considered in the choice of stains. Red, blue and green are part of the natural coloration of one or more species. The natural colors of the shrimp, the size when stained, and the length of time the mark must remain visible also should be considered in determining the correct amount of stain to be injected. The amount injected should be the smallest amount that will produce a mark satisfactory for a particular study. Any undesirable effects of the stain increase with dosage.

The methods now followed at the Bureau of Commercial Fisheries Biological Laboratory Galveston, Texas, for staining pink shrimp (Penaeus duorarum Burkenroad), brown shrimp (Penaeus aztecus Ives) and white shrimp (Penaeus setiferus Linnaeus) are discussed below.

2.2 Injection procedure

Fresh solutions of stain are mixed before each day's staining because some toxicity may develop in solutions held for more than 1 day (Costello, 1964). Staining solutions are filtered through No. 1 filter paper to remove large particles.

If a quantity of less than 0.1 ml is injected into each shrimp, a small tuberculin syringe with a 6.35-mm (1/4-in), 30-gauge needle is used. If more than 0.1 ml is injected, the use of a continuous pipetting outfit equipped with a 1-ml Luer-Lok syringe and a 26-or 27-gauge needle facilitates the injection procedure (Fig. 2).

A satisfactory injection site is the articular membrane between the 3rd and 4th abdominal segments. The needle is inserted laterally to minimize injury to the gut,

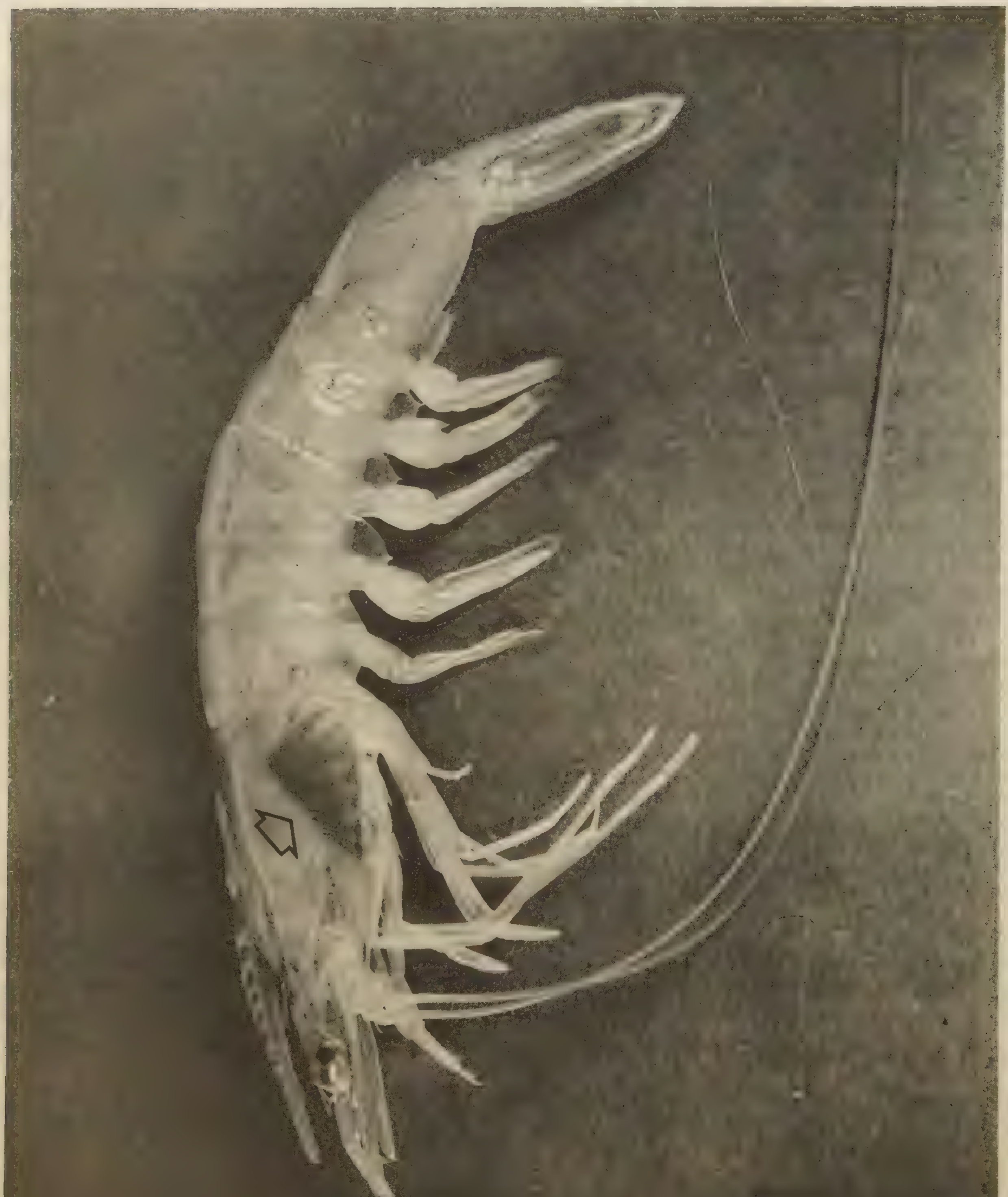

Fig. 1 Penaeid shrimp stained by injection of Niagara sky blue.

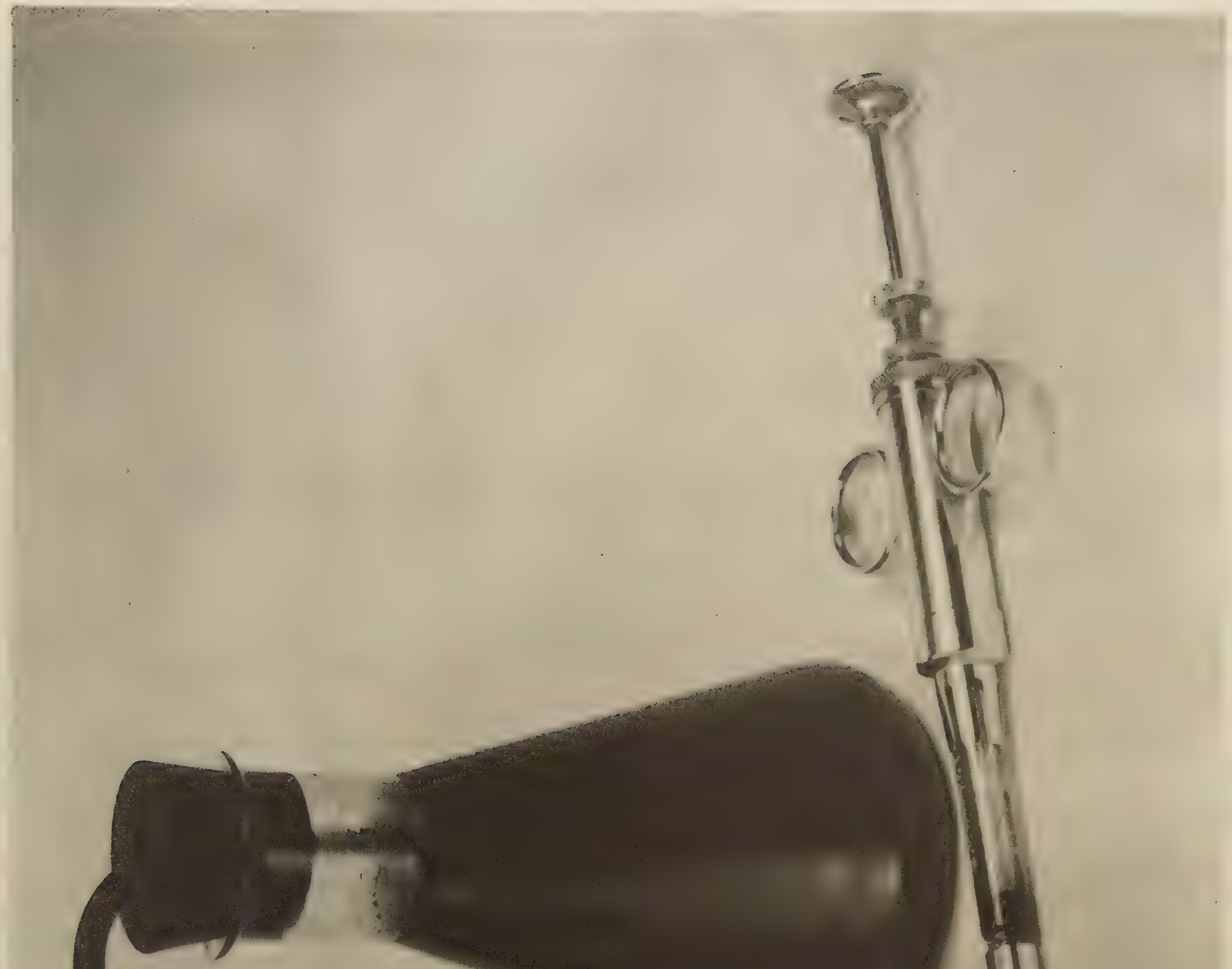

Fig. 2 Continuous pipetting outfit used for rapid injection of biological stains.

arteries or nerve cord (Fig. 3). Insertion of the needle through the articular membrane minimizes breakage of the exoskeleton and clogging of the needle with bits of exoskeleton.

2.3 Stains

Fast green FCF mixed with distilled water to form a 0.5% solution of the stain is used for marking shrimp. The amount injected per shrimp ranges from 0.03 to 0.30 ml depending on the size of the shrimp. Because it contrasts sharply with the natural color of shrimp, the green color in the gills is still readily visible after several months. This color fades gradually over a period of 2 to 3 mo so that the vividness of the mark decreases. Nevertheless, it has been used in large-scale field experiments with pink, brown and white shrimp. Recovery of as many as 62% of the shrimp stained and released in these experiments indicates that the adverse effects of the stain are slight, possibly negligible.

Comparison of oxygen uptake of shrimp stained with Fast green FCF with that of unstained shrimp by Zein-Eldin and Klima (1965) disclosed no appreciable difference between the stained and unstained shrimp.

Niagara sky blue 6B in concentrations of 0.25% in distilled water is also used as a shrimp stain. This stain is injected in quantities of 0.03 to 0.30 ml per shrimp. Shrimp retain a vivid blue color in their gills for at least 5 to 6 mo. Shrimp have been stained with Niagara sky blue in field experiments with resulting returns as great as 30% of those released.

Trypan blue likewise has been used successfully in a number of mark-recapture experiments. The color of this stain is retained so well that only small amounts are required to produce a satisfactory mark. When a 0.25% solution of Trypan blue in distilled water is used, 0.03 to 0.15 ml per shrimp is adequate to produce a lasting mark. Costello (1964) demonstrated that Trypan blue and Trypan red are more toxic to pink shrimp than Fast green. The highest percentage of returns of shrimp marked with Trypan blue has been 33%.

Trypan red was used successfully to mark shrimp under laboratory conditions (Dawson, 1957; Costello, 1964). The stain has no apparent value for field studies in the Gulf of Mexico because the natural colors of the shrimp are similar to the color of this stain. Dawson (1957) reported that this stain was clearly visible in the gills of shrimp 8 mo after injection. Quantities of 0.03 to 0.20 ml of a 0.50% solution in distilled water were injected into each shrimp.

Blue and green machine inks injected into shrimp, produced marks satisfactory for short-term studies (Klima, 1965). They faded within 1 week, but apparently did not cause mortality of the shrimp. These inks have not been tested in field experiments.

The sources of stains and marking materials used at the Bureau of Commercial Fisheries Biological Laboratory at Galveston, are identified in Table I.

3 STAINING BY FEEDING

Dawson (1957) stained small pieces of mullet, Mugil cephalus Linnaeus, with 23 different stains and fed varying quantities to shrimp. Although these feedings caused staining of the anterior digestive tract, some of the stains caused mortality, and fading of the stained area usually was rapid.

4 STAINING BY IMMERSION

The simplicity of staining by immersion and the fact that no physical injury is inflicted upon the shrimp make the possibility of using this method attractive. Results

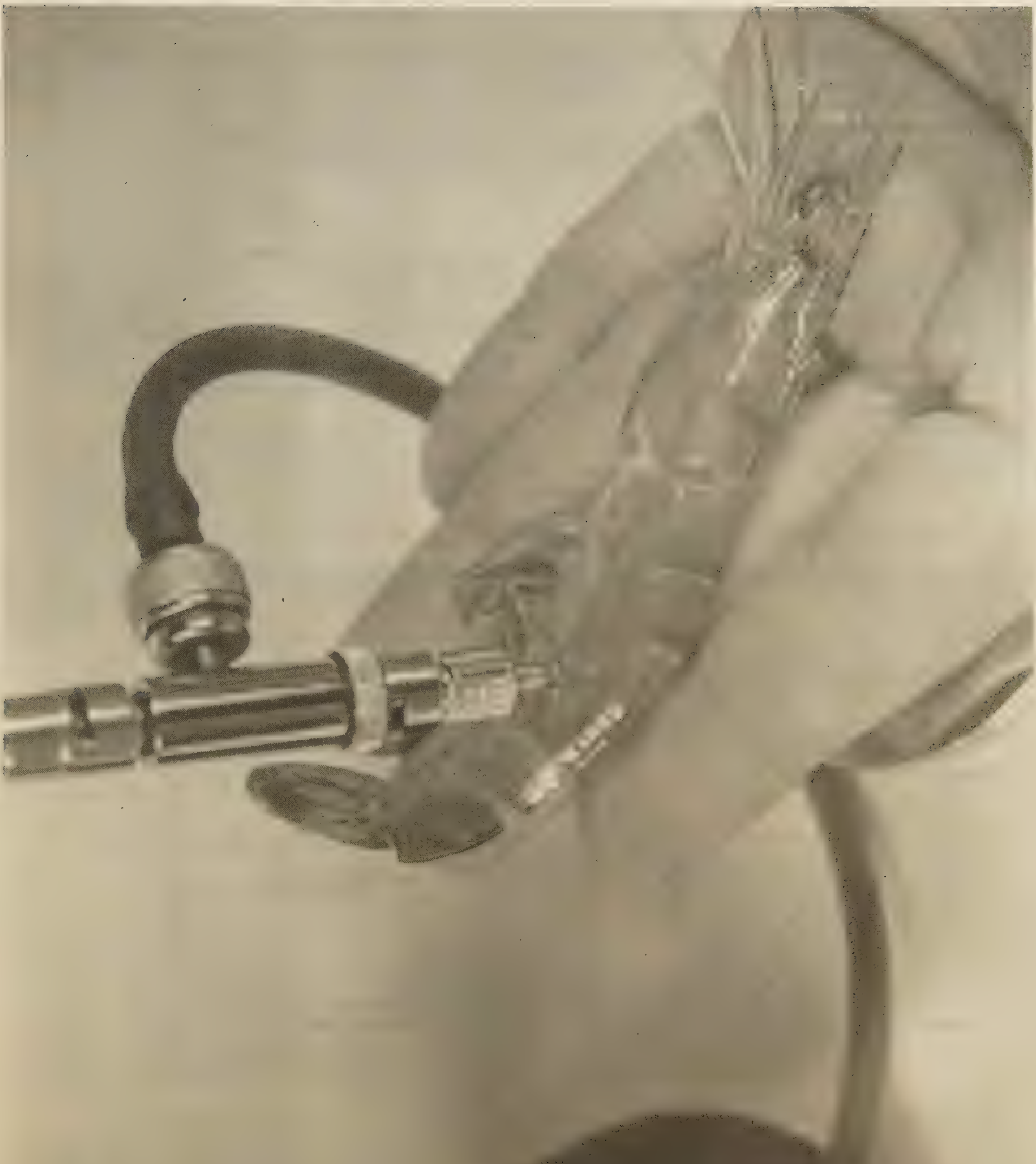

Fig. 3 Injection site for biological stains.

TABLE I

Sources of marking materials used by the Bureau of Commercial Fisheries at the Biological Laboratory, Galveston, Texas[1]

Marking material	Source
Fast green FCF Niagara sky blue 6B Trypan blue Trypan red Nile blue A Neutral red	Hartman-Leddon Company Philadelphia, Pennsylvania
Blue and green machine inks	Bates Manufacturing Company Orange, New Jersey
Red and blue food coloring	French Food Company Rochester, New York
Color-coded, wire tags	Technical Research Company Seattle, Washington
Day-Glo fluorescent pigments (Saturn yellow, Blaze orange, Arc yellow, and Neon red)	Switzer Brothers, Inc. Cleveland, Ohio
Polyvinyl chloride internal tags	Floy Tag Company Seattle, Washington

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1/ Trade names referred to in this publication do not imply endorsement of commercial products.

of immersion staining experiments are inadequate, however, to determine if stains are retained through the molting process.

The use of immersion techniques for marking shrimp was discussed by Racek (1956). Of four stains tested, he concluded that two (Trypan blue and Nile blue sulfate) were partially satisfactory. Shrimp stained with Trypan blue had a distinctive nonfading blue tint 2 weeks after immersion. However, about half the shrimp immersed in a solution of Trypan blue for 2 min died after removal from the solution. Racek (1956) stated that Nile blue sulfate was the most promising stain tested. Shrimp were immersed 3 to 4 min in a 0.1% solution of Nile blue sulfate in sea-water. The mark produced was retained for "a long period".

Dawson (1957) tested Alizarin red S, Bismark brown Y, Janus green B, Methyl green, Nile blue sulfate, Trypan blue, Trypan red, and Fast green FCF to determine their effectiveness as immersion stains. Marks produced by immersion in solutions of all except the last disappeared within 4 days. Immersion of shrimp for 15 min in a 0.75% solution of Fast green FCF in sea water produced some coloration visible up to 6 days after marking.

Immersion staining methods were also examined by Wheeler (1963) who was searching for a method of marking postlarval shrimp. Solutions of 11 stains, including liquid food colorings and biological stains, were tested in different concentrations. When shrimp 10 mm in total length (tip of rostrum to tip of telson) were immersed for 10 min in red and blue food colorings, their digestive tract was stained heavily enough so that color was visible 2 to 3 days later, although fading began immediately after their removal from the solution. Immersion of shrimp in solutions of Nile blue A and Neutral red produced staining of the abdominal tissues which was visible for at least 7 and 14 days, respectively.

The need to mark large numbers of Crangon crangon (Linnaeus) led to the examination of various dyes to determine if any were suitable as an immersion stain (Meyer-Waarden and Tiews, 1965). They learned that immersion for 3 to 5 min in a 0.10% solution of methyl violet "gentiana violet B" provided a mark suitable for short-term studies. The stain faded after several weeks, and all traces of the stain disappeared when the animals molted. This method may be of value for studies of shrimp movements or mortality during a single intermolt period.

5 EXTERNAL TAGS

5.1 Petersen disk tags

Petersen disk tags have been used in a number of studies with several species of shrimp. Extensive studies in which these tags were used were those conducted with white shrimp by Lindner and Anderson (1956). Red and white celluloid disks, individually numbered, 7.9 to 9.5 mm in diameter and 0.25 mm thick were attached to shrimp with a nickel wire pin. One disk was placed on each side of the shrimp, and the pointed end of the pin was bent into a loop so that the disks could not be lost. The pin was inserted through the musculature of the 1st abdominal segment (Fig. 4).

During this study by Lindner and Anderson (1956), the number of deaths resulting from the effects of tagging were higher for small than for large shrimp within the size range 80 to 135 mm total length. Data from returns of this tag were used to determine the migrations and growth rates for this species along the southern Atlantic coast and the Gulf coast of the United States. Of a total of 45,022 shrimp tagged and released, 7,167 or 16% were recovered.

5.2 Wire tags

A silver wire tag with small plastic disks has been used for mark-recapture studies of C. crangon (Kourist, Mauch and Tiews, 1964; Meyer-Waarden and Tiews, 1965; and Tiews,

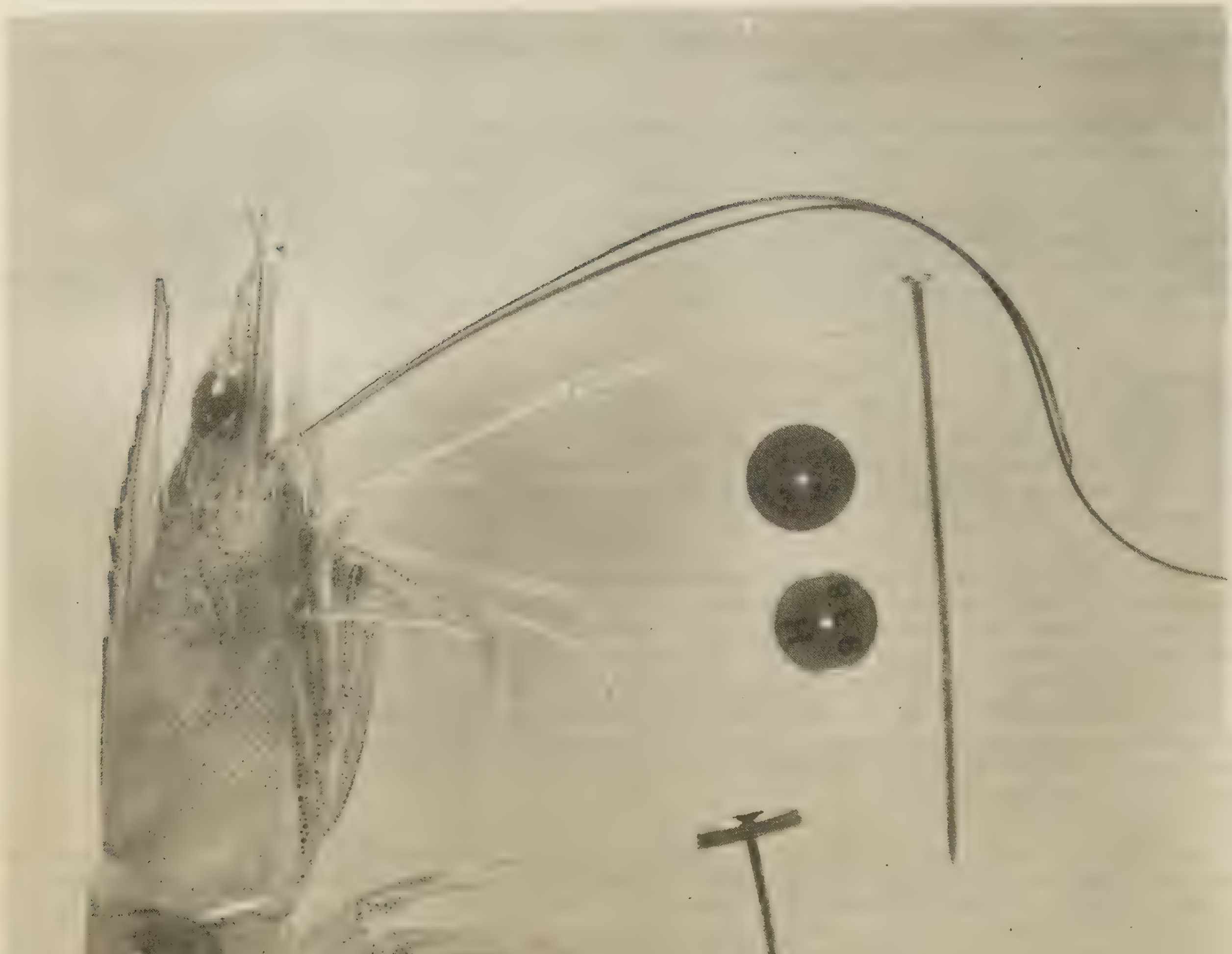

Fig. 4 Shrimp marked with the Petersen disk tag.

1967). The wire, 0.18 mm in diameter, is wrapped around the shrimp between the carapace and the 1st abdominal segment. Colored plastic disks 6 mm in diameter are attached to the wire. Some shrimp marked in this way were recovered more than 5 mo after their release and had apparently molted without difficulty while the tag was in place.

5.3 Dart- and loop-type tags

A variety of dart- and loop-type tags have been tested under laboratory conditions at the Galveston Biological Laboratory. These tags were attached to shrimp at several sites on the cephalothorax and abdomen but the junction between the cephalothorax and abdomen was used most frequently. Because the exoskeleton splits at this location during ecdysis, it is a preferred site for tags.

Dart- and loop-type tags which protruded through the exoskeleton frequently caused serious infections. Even though some tagged shrimp survived for several months, the constant irritation prevented healing of the wound, and the infection persisted. Antibiotics applied with the tag did not eliminate infections. These tags may be of value in studies of migration routes, but mortality and growth rates of shrimp are probably affected by the tags.

6 INTERNAL TAGS

6.1 Coded-wire tags

A magnetized color-coded wire tag (Jefferts, Bergman and Fiscus, 1963) has been tested as a means of marking Pandalus platyceros Brandt (West, 1967, West and Chew, 1968; and Chew, personal communication). These cylindrical, stainless steel tags 1.0 mm long and 0.25 mm in diameter were injected into the musculature of the 1st abdominal segment. The tagged shrimp were held in aquaria for 50 days without any apparent mortality from tagging. Molting of the tagged shrimp was as frequent as that of untagged controls, and the wounds caused by insertion of the tags healed rapidly. Vertical stripes of colored epoxy paint were applied to wire tags for identification. The numerous possible combinations permit the identification of groups of tagged individuals. An automatic device which injects these tags rapidly into the same position in each animal has been developed by the Technical Research Company. After being inserted into the animals, the tags are magnetized so that they may be detected when the shrimp are passed through an electronic detector.

6.2 Vaseline-pigment marks

In addition to a mark which is easily detected (primary mark), secondary marks may be applied to shrimp to provide a means of identifying individual shrimp or groups of shrimp.

The method of marking with a Vaseline-pigment mixture was developed to aid in recognition of groups of shrimp marked with biological stains (Klima, 1965). Minute quantities (0.003 to 0.010 ml) of mixtures of 1.3-percent Day-Glo fluorescent pigment in Vaseline are injected into the abdominal musculature of the 4th and 5th abdominal segments. Four pigments - Saturn yellow, Blaze orange, Arc yellow and Neon red - can be distinguished readily under ultraviolet light.

Although Klima (1965) stated that the pigment usually remained at the injection site, he observed traces of pigment in the ventral sinuses and gills. Further studies of shrimp marked with the Vaseline-pigment mixture have revealed that particles of the mixture gradually move towards the gill region during a period of several weeks and accumulate in the gills. This movement is particularly apparent if excessive amounts of the Vaseline-pigment mixture are administered.

During the experiments conducted by Klima (1965), the Vaseline-pigment mixture in the bodies of shrimp apparently did not affect their survival. In more recent experiments, however, the mean survival time of shrimp marked with primary and secondary stains was slightly lower than that of unmarked shrimp or of those marked with only a primary stain. The secondary mark has been used by personnel of the Biological Laboratory at Galveston in several field experiments; the percentage returned has been similar for stained shrimp with and without the secondary mark.

6.3 Polyvinyl chloride tags

For identifying individual shrimp marked with a biological stain, personnel at the Biological Laboratory at Galveston developed a small internal tag which can be numbered. This tag is polyvinyl chloride 0.25 mm thick and is about 5 mm by 2 mm (Fig. 5). Slender forceps are used to insert the tag into the musculature of the 1st abdominal segment through the articular membrane joining the carapace with the 1st abdominal segment. The tags are inserted laterally to minimize damage to the nervous, digestive or circulatory systems (Fig. 6). Mortality of tagged and untagged shrimp held in the laboratory was not significantly different.

Polyvinyl chloride tags were used recently in a series of field experiments with brown shrimp. All shrimp were stained with Niagara sky blue so that they would be recognized by commercial fishermen. In addition, shrimp were marked secondarily with either the polyvinyl chloride tag or a small quantity of a fluorescent Vaseline-pigment mixture as described earlier. About 20,000 marked shrimp were released in three separate experiments during May and June 1967. Of the 13,000 tagged shrimp released, 4.6 percent were returned, and 4.5 percent were returned from the 7,000 marked secondarily with the Vaseline-pigment mixture. Mortalities from marking with this tag apparently were no more severe than those caused by the Vaseline-pigment mark.

7 AIDS IN HANDLING SHRIMP

7.1 Anesthetics

The vigorous activity of shrimp during handling and marking often results in injuries to the shrimp and loss of time to those doing the marking. Zein-Eldin (1963) conducted tests with sodium pentabarbital, ethclorovynol, methylparafynol, tribromoethanol, chlorobutanol, methol and tricaine methanesulfonate to determine which might be suitable as an anesthetic for penaeid shrimp. Results reported by Zein-Eldin are as follows: "The effective anesthetic dose for postlarval shrimp was found in all cases to be at least 10 times greater than that for fish of comparable weight. Moreover, there is a very narrow concentration range in which rapid sedation can be obtained and maintained without fatality."

7.2 Holding shrimp

Despite reasonable precautions taken to avoid injuring shrimp, some shrimp are injured seriously as a result of handling and marking. In making estimates of rates of fishing mortality, it is desirable to have a reliable estimate of the number of shrimp released. In mark-recapture experiments conducted by the Galveston Laboratory, shrimp are usually held aboard the research vessel for 12 h after marking to minimize post-release mortalities caused by the marking.

Two serious problems that arise when shrimp are held aboard vessels at sea are the turbulence in the holding tanks caused by the constant motion of the vessel, and the fact that water temperatures in holding tanks may be different from the shrimps' natural environment. Because of the turbulence, shrimp are tossed about in the tanks with each sudden movement of the vessel and must swim continuously. To counteract this turbulence, baffles are placed in the holding tanks and irregular surfaces are provided to which the shrimp may cling. Water being held on the vessel may be warmed by the

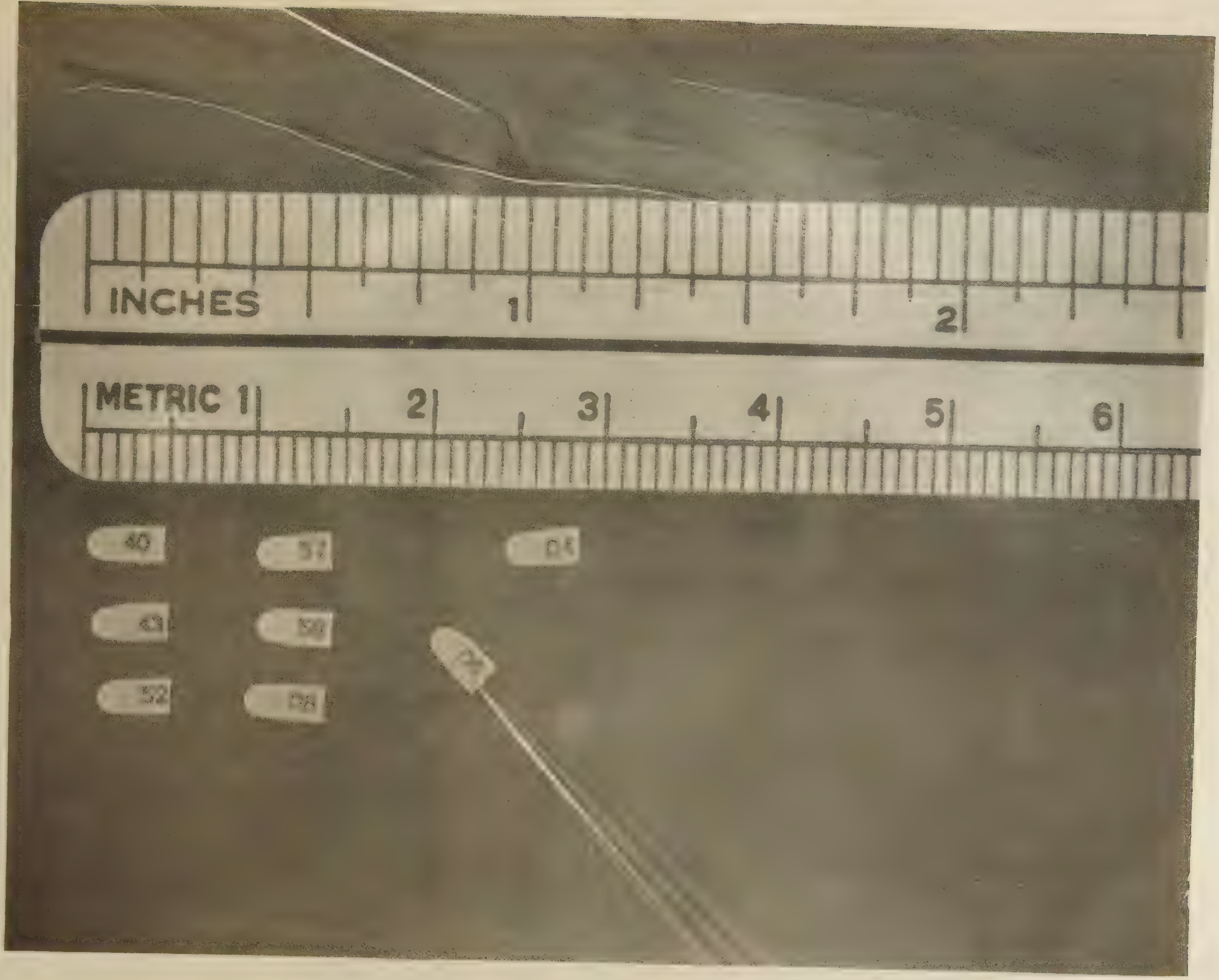
INCHES
1
2
METRIC 1
2
3
4
5
6
40
57
43
50
52

Fig. 5 Internal polyvinyl chloride shrimp tags.

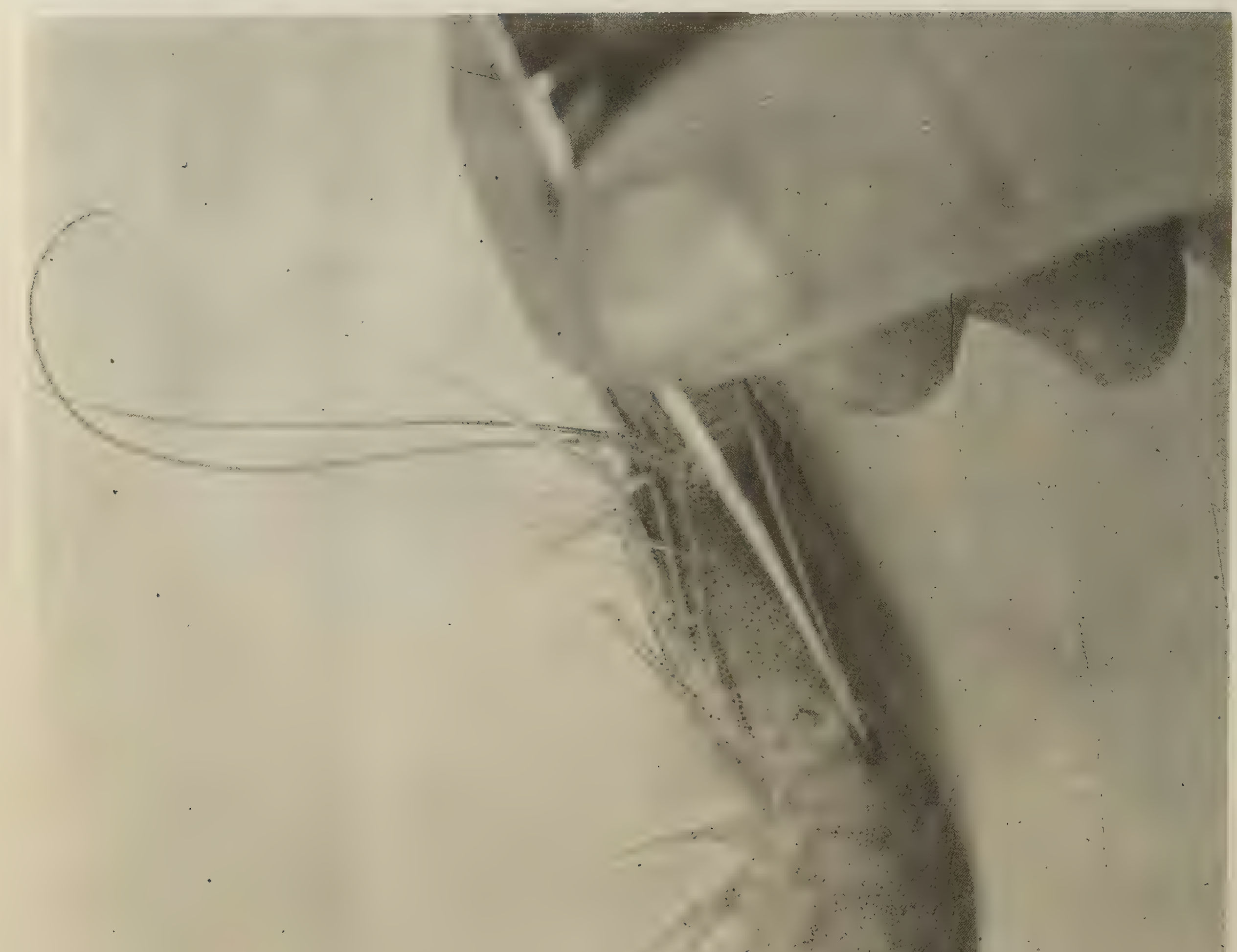

Fig. 6 Method of insertion of internal polyvinyl chloride tags.

air and sun, or, if surface water is being pumped into the holding tanks, it may be warmer than the water from which the shrimp were taken. The temperature change to which the shrimp then are subjected along with resulting changes in metabolic rates and oxygen demand may make it impossible to hold live shrimp for any extended period. Refrigeration of the water in the holding tanks to 2° to 5°C below the temperature of the bottom water eliminates this problem and reduces the metabolic rate of the shrimp. This chilling requires, however, the use of a closed system in which the water must be changed regularly if live shrimp are to be held successfully.

7.3 Methods of releasing marked shrimp

Predation at the time of release may cause losses of the marked shrimp. These losses bias mortality estimates based on the number of marked individuals released. Because birds and fish prey upon marked shrimp released at the surface, several types of release boxes have been designed to insure that shrimp reach the botton. The use of these devices increases the shrimps' chances of being able to burrow into the substrate before predators capture them.

Release canisters presently in use at the Biological Laboratory at Galveston are disposable and can be used while the vessel is underway (Benigno and Emiliani, personal communication). They are constructed from resilient styrene sheets and have a release mechanism consisting of a rubber band and salt block. The size of the salt block determines the time elapsing before the shrimp within the box are released (Fig. 7).

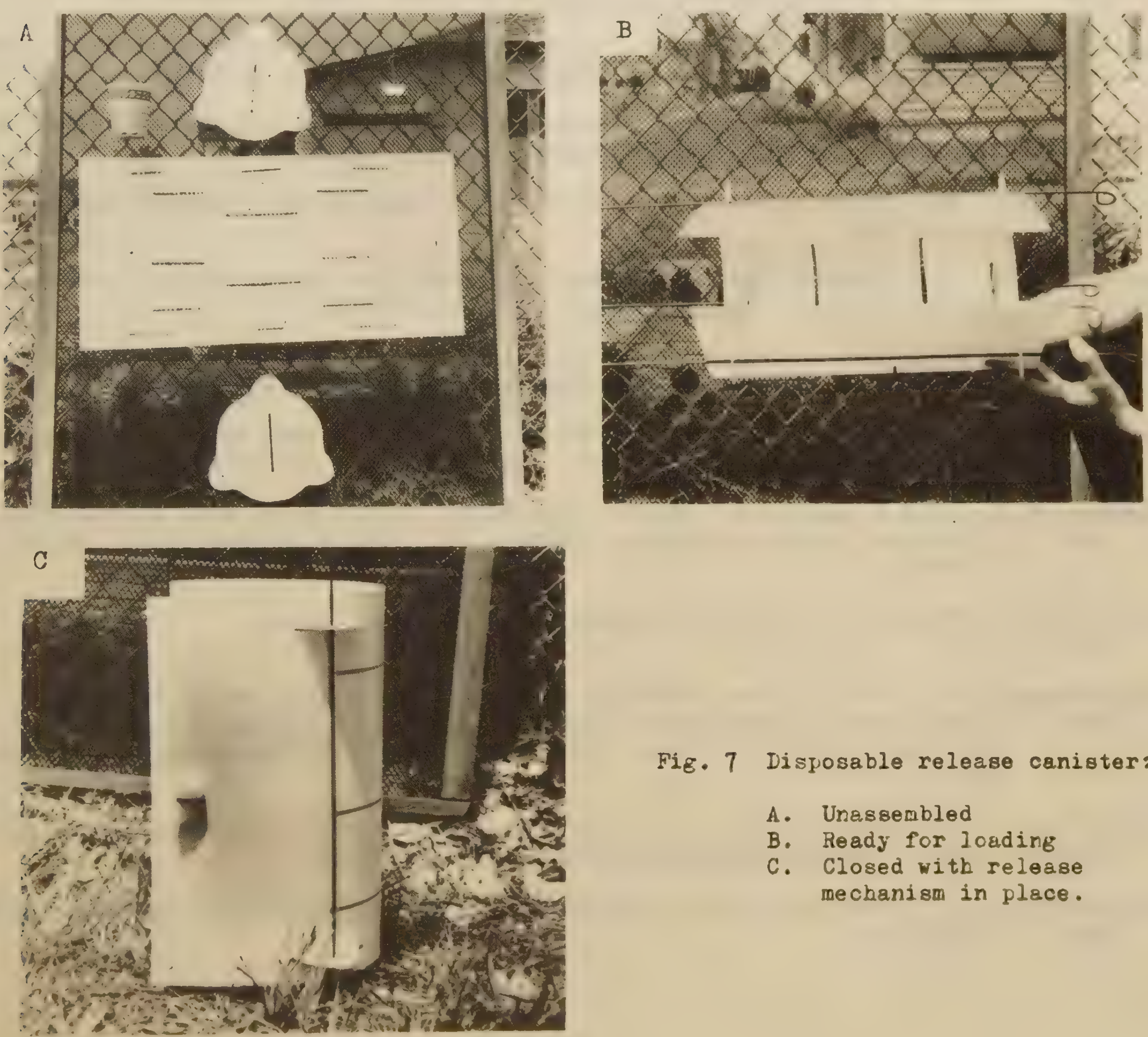

Fig. 7 Disposable release canister:

A. Unassembled
B. Ready for loading
C. Closed with release
mechanism in place.

8 CONCLUDING REMARKS

Because no method of marking shrimp is ideal, the method best suited for each particular study must be chosen by considering the harmful effects of a mark against its advantages. Factors limiting the types of marks which may be used successfully are the behavior of the species, the conditionsunder which it is being captured and marked, and the specific information being sought.

Several types of marks discussed in this paper have not been used extensively but show promise. Continual refinement of known marking methods and development of new techniques are an important part of shrimp research.

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